

# THE 1998 PROJECT SUMMARY BOOK

A Summary of AWWA Research Foundation Projects



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## Thanks to all Foundation subscribers for their ongoing commitment to advancing the science of water

#### 1998

ALABAMA: Birmingham Water Works Board ♦ Decatur Water Department & East Alabama Water, Sewer & Fire Protection Authority, Valley . Huntsville Utilities . City of Montgomery Water Works & Sanitary Sewer Board ◆ Schlumberger Industries, Tallassee ◆ ALASKA: Anchorage Water and Wastewater Utility 

♦ College Utilities Corporation, Fairbanks & Golden Heart Utility, Fairbanks & ARIZONA: Chandler Municipal Water Department City of Glendale Utilities Department & HDR Engineering, Inc., Phoenix 

John Carollo Engineers, Phoenix 

City of Mesa • Paradise Valley Water Company, Scottsdale • City of Peoria & Phoenix Water & Wastewater Department **♦** Salt River Project, Phoenix **♦** City of Scottsdale Water Resources Department & Tempe Municipal Water Department & Tucson Water & ARKANSAS: Little Rock Municipal Water Works & North Little Rock Water Department ♦ United Water Arkansas ♦ CALIFORNIA: Adams Ranch Mutual Water Company, Rosemead & Alameda County Water District, Fremont & City of Alhambra & Amarıllo Mutual Water Company, Rosemead 

Anaheim Water Division ♦ City of Antioch ♦ Apple Valley Ranchos Water Company, Apple Valley 

◆ City of Arcadia 

◆ Atascadero Mutual Water Company & AZUR Environmental, Carlsbad **♦** City of Azusa **♦** City of Bellflower **♦** Bellflower Home Garden, Beliflower & Beliflower Somerset Municipal Water District ♦ Bigby Townsite Water Company, Bellflower ♦ City of Brea & Brown and Caldwell, Sacramento & City of Buena Park 

Burbank Public Service Department 

California-American Water Company, Chula Vista 

 California-American Water Company, Imperial Beach & California-American Water Company, Monterey 

California-American Water Company, San Marino 

◆ California Cities Water, Pittsburg . California Country Club, Whittier . California Domestic Water Company, Whittier & California State Polytechnic University, Pomona & California Water Service Company, San Jose ♦ Calleguas Municipal Water District, Thousand Oaks & Calmat Company, Los Angeles & Capistrano Valley Water District, San Juan Capistrano ▶ Castaic Lake Water Agency, Santa Clarita ♦ Central Basin Municipal Water District & Central Coast Water Authority, Santa Barbara . City of Cerritos . Champion Mutual Water Company, El Montes & Charlotte Smith & Associates, Inc., Jrında ♦ Cıty of Chino ♦ Chino Basın Watermaster ♦ Cıty of Chino Hills & Citrus Heights Irrigation District & Coachella 'alley Water District ♦ City of Commerce ♦ City of Compton Aunicipal Water District 

◆ Contra Costa Water District, Concord ♦ City of Cotati ♦ City of Covina ♦ Covina rrigating Company, Covina & Crescenta Valley County Water District, La Crescenta & Crown City Plating Company, El Aonte 

♦ Cucamonga County Water District, Cucamonga Del Rio Mutual Water Company, El Monte 

◆ Desert Water Igency, Palm Springs . Diablo Water District Oakley . Jominguez Water Corporation, Long Beach 

◆ City of Jowney 

Dublin San Ramon Services District, Dublin 

East 3ay MUD, Oakland 

◆ East Orange County Water District, )range ♦ East Pasadena Water Company, Ltd., Pasadena › East Valley Water District, San Bernardino ♦ Eastern Aunicipal Water District, San Jacinto & City of El Monte ▶ El Segundo Water Department • El Toro Water District, aguna Hills ♦ City of Escondido ♦ City of Fairfield ♦ Foothill Aunicipal Water District, La Canada Flintridge 

◆ Forestville 'ounty Water District & Fountain Valley Water Department City of Fullerton ♦ Garden Grove Water Services ♦

Glendale Public Services Department ♦ City of Glendora ◆ City of Hawthorne Water Department
 ◆ Helix Water District, La Mesa & Hemlock Mutual Water Company, El Monte ♦ City of Hesperia Water District ♦ Humboldt Community Service District, Cutten & Huntington Beach Municipal Water Department 

City of Huntington Park Service Department & Irvine Ranch Water District & Jurupa Community Services District, Riverside & Kennedy/Jenks Consultants, San Francisco & La Canada Irrigation District, La Canada Flintridge & La Habra Heights Water District City of La Habra Waterworks → City of Lakewood → City of La Palma & La Puente Valley County Water District, La Puente 

Las Flores Water Company, Altadena 

Las Virgenes Municipal Water District, Calabasas & City of LaVerne Water Department & Lincoln Avenue Water Company, Altadena 

◆ City of Livermore 

◆ Livingston-Graham, Inc , Irwindale ♦ City of Lodi Public Works ♦ City of Lomita 

Long Beach Water Department 

Los Alisos Water District, El Toro ♦ Los Angeles County Department of Public Utilities, Alhambra & Los Angeles Water & Power & City of Lynwood ♦ Lynwood Park Mutual, Compton ♦ Main San Gabriel Watermaster, Azusa & City of Manhattan Beach Utilities Division . Maple Water Company, Inc., City of Industry & Marin Municipal Water District, Corte Madera ♦ City of Martinez ♦ Marygold Mutual Water Company. Bloomington & Maywood Mutual Water Company No 1, Maywood & Maywood Mutual Water Company No 3, Maywood 

McGure Environmental Consultants, Inc., Santa Monica & Mesa Consolidated Water District, Costa Mesa ♦ Metropolitan Water District of Southern California, Los Angeles 

Miller Brewing Company, Irwindale 

City of Montebello Land and Water Company ← City of Monterey Park 

Monte Vista Water District, Montclair 

Montgomery Watson Consulting Engineers, Pasadena & Moulton Niguel Water District, Laguna Niguel & Mount San Antonio College, Walnut 

Municipal Water District of Orange County, Fountain Valley & Mutual Water Company of Glen Avon Heights, Riverside & Nevada Irrigation District, Grass Valley 

◆ City of Newport Beach Water Department 

◆ City of Norco & North Marin Water District, Novato & North of the River MWD, Bakersfield & Northridge Water District, Sacramento 

◆ City of Norwalk 

◆ City of Oceanside 

◆ City of Ontario & City of Orange & Orange County Water District, Fountain Valley & Orchard Dale Water District, Whittier **♦** Owl Rock Products, Arcadia **♦** Padre Dam Municipal Water District, Santee 

◆ Palmdale Water District 

◆ City of Paramount & Park Water Company, Downey & Pasadena Water & Power Department • Peerless Water Company, Bellflower ♦ City of Petaluma ♦ City of Pico Rivera ♦ Pico Water District, Pico Rivera ♦ City of Pittsurg ♦ City of Pleasanton 

◆ City of Pomona 

◆ Queen of the Valley Hospital, West Covina ♦ Ramona Municipal Water District ♦ Rancho California Water District Temecula . City of Riverside Public Utilities • City of Rohnert Park • Rose Hills Memorial Park Association, Whittier & Rowland Water District, Rowland Heights ♦ Rubio Canon Land & Water Association, Altadena ♠ Rurban Homes Mutual Water Company, El Monte ♠ Sacramento Water & Sewer Division 

♦ San Antonio Water Company, Upland ♦ San Bernardino Municipal Water Department & San Diego County Water Authority, San Diego Water District Encinitas & San Francisco Water Department

County Water District, San Gabriel & San Gabriel Valley Municipal Water District, Azusa ♦ San Gabriel Valley Water Company, El Monte 

◆ City of San Jose Municipal Water System • San Jose Water Company • Santa Ana River Water Company, Mira Loma 

◆ Santa Ana Utilities Agency 

◆ City of Santa Barbara & Santa Clara Valley Water District, San Jose ♦ Santa Cruz Water Department ♦ Santa Fe Irrigation District, Rancho Santa Fe ♦ City of Santa Fe Springs ♦ Santa Margarita Water District, Mission Viejo & City of Santa Maria ♦ City of Santa Rosa ♦ Santiago County Water District, Silverado & Sativa Los Angeles County Water, Compton ♦ Scotts Valley Water District ♦ City of Seal Beach Water Department & Serrano Irrigation District, Villa Park **♦** City of Sierra Madre **♦** City of Signal Hill **♦** City of Sonoma & Sonoma County Water Agency, Santa Rosa & Soquel Creek Water District, Soquel & South Coast Water District, Laguna Niguel 

◆ City of South Gate 

◆ South Montebello Irrigation, Montebello & City of South Pasadena ♦ Southern California Water Company, San Dimas ♦ Sterling Mutual Water Company, El Monte 

Suburban Water Systems, La Puente & Sunny Slope Water Company, Pasadena Municipal Water District, Claremont ♦ Torrance Municipal Water Department 

Trabuco Canyon Water District 

Tract #180 Water Company, Cudahy . Tract #349 Water Company, Cudahy 

City of Tustin Water Services 

United Rock Products Corporation, Irwindale ♦ City of Upland ♦ Upper San Gabriel Valley Municipal Water District, El Monte Water Company, West Covina & Vallecitos Water District, San Marcos & Valley County Water Distict, Baldwin Park Valley of the Moon Water District, El Verano Valley View Mutual Water Company, Baldwin Park & Valley Water Company, La Canada Flintridge 

◆ City of Vernon 

◆ Vista Irrigation District & Walnut Park Mutual Water Company, Huntington Park & Walnut Valley Water District, Walnut ♦ Water Replenishment District of Southern California, Cerritos • West Basin Municipal Water District, Redondo Beach & West San Bernardino County Water District, Rialto Western MWD of Riverside County, Riverside → Westin Engineering, Inc., San Jose & City of Westminster Water Department ♦ City of Whittier ♦ Woodward-Clyde Consultants, Oakland & Yorba Linda County Water District, Yorba Linda & Zone 7 Water Agency, Pleasanton ♦ □□□RAD□: Aquacraft, Inc., Boulder ♦ Battlement Mesa Metro District . Boyle Engineering Corporation, Lakewood 

◆ City of Broomfield Water Department ♦ CH2M Hill Consulting Engineers, Denver Administration & Crestview Water & Sanitation District. Denver ♦ Denver Water Department ♦ City of Englewood ♦ Town of Estes Park ♦ City of Fort Collins Water Department ◆ City of Grand Junction
 ◆ Hach Company, Loveland
 ◆ Northwest Pipe Company • Platte Canyon Water and Sanitation District, Littleton & Process Applications, Inc., Fort Collins 

◆ Pueblo Board of Waterworks 

◆ Richard P Arber Associates, Denver & Stratus Consulting Inc., Boulder ♦ City of Thornton ♦ Wheat Ridge Water District ♦ CONNECTICUT: BHC Company, Bridgeport • Birmingham Utilities, Inc , Ansonia ♦ Connecticut- American Water Company, Greenwich 

♠ Connecticut Water Company, Clinton 

◆ Danbury Water Department 

◆ Groton Water Department ◆ Hartford Metropolitan District ◆ Heitkamp, Incorporated, Watertown ♦ City of New Britain ♦ Norwalk

Second Taxing District Water Department • Norwich Department of Public Utilities ♦ South Central Connecticut Regional Water Authority, New Haven • United Water Connecticut, New Milford & DELAWARE: Artesian Water Company, Wilmington ♦ Board of Water & Light Commissioners, New Castle & United Water Delaware, Claymont & DISTRICT OF COLUMBIA: Washington Aqueduct Division ♦ FL□RIDA: Bal Harbour Village & City of Boynton Beach & Broward County Utilities Department, Pompano Beach ♦ Camp Dresser & McKee Inc., Orlando ♦ City of Cocoa ♦ Florida Cities Water Company, Sarasota & Florida Keys Aqueduct Authority, Key West ♦ Florida Water Services Corporation ♦ Florida Water Services Corp , Amelia Island, Fernandina Beach ♦ Florida Water Services Corp , Beacon Hills WWTP, Jacksonville & Florida Water Services Corp , Buenaventura, Kissimmee & Florida Water Services Corp , Burnt Store, Punta Gorda & Florida Water Services Corp., Citrus Springs ♦ Florida Water Services Corp , Commerce Park, Longwood & Florida Water Services Corp , Deep Creek ♦ Florida Water Services Corp , Deltona ♦ Florida Water Services Corp , Keystone Heights ♦ Florida Water Services Corp , Lake County, Leesburg & Florida Water Services Corp , Lake Gibson, Lakeland & Florida Water Services Corp, Lehigh ♦ Florida Water Services Corp , Marco Island ♦ Florida Water Services Corp , Marion Oaks, Ocala & Florida Water Services Corp , Seaboard, Tampa ♦ Florida Water Services Corp , Spring Hill & Florida Water Services Corp , Sugar Mill C C, New Smyrna Beach ♦ Florida Water Services Corp , Sugarmill Woods, Homosassa Springs ♦ Florida Water Services Corp , University Shores, Orlando ♦ Florida Water Services Corp , Woodmere WTP, Jacksonville & City of Fort Lauderdale Gainesville Regional Utilities . Hialeah Department of Wtaer & Sewer ♦ Hialeah Gardens Water Department ♦ Hillsborough County Utilities, Tampa ♦ City of Hollywood ♦ City of Homestead Utilities ♦ Indian Creek Village 

◆ City of Jacksonville 

◆ City of Kissimmee 

◆ Lakeland Electric & Water Utilities . Town of Long Boat Key . Manatee County Utilities Department, Bradenton ♦ Martin County Utilities, Jensen Beach 

Medley Department of Water & Sewer ♦ Miami Beach Department of Public Works 

Miami-Dade Water and Sewer Department, Coral Gables ♦ Miami Springs Department of Public Works ♦ City of New Port Richey . North Bay Village . City of North Mıamı Beach ♦ Opa Locka ♦ Orange County Public Utilities Division, Orlando ♦ Orlando Utilities Commission ♦ Palm Beach County Utilities Department, West Palm Beach ♦ City of Palmetto ♦ Pasco County Utilities, New Port Richey ♦ Pinellas County Water System, Clearwater • Post, Buckley, Schuh & Jernigan, Inc , Miami • City of Saint Petersburg Sarasota County Utilities, Sarasota ♦ Seacoast Utilities, Tampa City Water Department ♦ United Water Florida, Jacksonville ♦ United Water South Gate, Sarasota ♦ GEORGIA: Athens-Clarke County Public Utilities Department, Athens & The City of Atlanta Department of Water ♦ Clayton County Water Authority, Morrow ♦ Cobb County-Marietta Water Authority, Acworth ♦ Cobb County-Manetta Water Authority, Manetta ♦ Columbus Water Works 

◆ Fayette County Water System, Fayetteville 

◆ Macon-Bibb County Water & Sewerage Authority, Macon ► HAWAII: Hawaii County Dept Water Supply, Hilo Honolulu Board of Water Supply . Kauai County Department of Water, Lihue . Maui County Board of Water Supply, Wailuku ♦ IDAHD: United Water Idaho ♦ **!LLINDIS:** Village of Arlington Heights ♦ City of Bloomington ♦ Village of Buffalo Grove ♦ Carus Chemical Company Peru . Central Lake County Joint Action Water Agency, Lake Bluff 

♦ Chicago Department of Water 

• Commonfields of Cahokia Public Water District Cahokia ♦ Consoer Townsend Envirodyne Engineers Inc., Chicago ♦ Consumers Illinois Water Company, Danville & Consumers Illinois Water Company, Kankakee & City of Elgin Water Department ♦ Evanston Water Utility ♦ Village of Grayslake Village of Lake Bluff ♦ Lake County Public Water District,

Zion ♦ Lake County Public Works, Libertyville ♦ Village of Libertyville ♦ Village of Mundelein ♦ City of Naperville Northern Illinois Water Corporation, Champaign ◆ Northwest Water Commission, Des Plaines ♦ Village of Palatine ♦ Village of Round Lake ♦ Village of Round Lake Beach ♦ Village of Round Lake Park ♦ Stiles Kem Division, Met Pro Corporation, Zion ♦ United Water Illinois ♦ Village of Wheeling ♦ Wilmette Water Plant ♦ INDIANA: HNTB Corporation, Indianapolis • Indiana-American Water Company, Greenwood & Indianapolis Water Company ♦ Northwest Indiana Water Company, Gary ♦ United Water Indiana Mooresville Operation • United Water Indiana Warsaw Operation • United Water Indiana Winchester Operation ♦ United Water West Lafayette ♦ I□WA: City of Ames Water Department • Cedar Rapids Water Department ♦ Des Moines Water Works ♦ Iowa-American Water Company ♦ Iowa City Water Division ♦ West Des Moines Water Works ♦ KANSAS: Kansas City Board of Public Utilities . Midland Resources, Inc., Lawrence . City of Olathe Water Department & Topeka Water Department 

♦ Water District #1 of Johnson County, Mission KENTUCKY: Aqua/KWS, Lexington ◆ Kentucky-American Water Company, Lexington 

♦ Louisville Water Company Northern Kentucky Water Service District, Covington ◆ Paducah Water Works ◆ L□LISIANA: Consolidated Waterworks District #1, Houma ♦ Lafayette Utilities System 

♦ New Orleans Sewerage 

& Water Board ◆ Parish Water Company, Baton Rouge ◆ MAINE: Auburn Water District ♦ Bethel Water District ♦ Brunswick & Topsham Water District, Brunswick & Consumers' Maine Water Company, Rockport & IDEXX Laboratories, Inc., Westbrook ◆ Portland Water District ◆ South Berwick Water District • MARYLAND: Anne Arundel County Department of Utilities, Annapolis & Baltimore Bureau of Water & Waste Water ♦ City of Hagerstown ♦ Howard County Department of Public Works, Ellicott City • Maryland-American Water Company, Bel Air ♦ O'Brien and Gere Engineers, Landover & Washington Suburban Sanitary Commission, Laurel ◆ MASSACHUSETTS: Town of Agawam ♦ Arlington Public Works Department **♦** Belmont Water Department **♦** Boston Water & Sewer Commission & Brookline Water and Sewer Department **♦** Cambridge Water Department **♦** Canton Department of Public Works . Chelsea Public Works Department . Chicopee Water Department & Clinton Department of Public Works ♦ Town of East Longmeadow ♦ Everett Public Works Department 

Fay, Spofford & Thorndike, Lexington 

In the state of t Framıngham Public Works Department ♦ Leominster Public Works Department & Lexington Water and Sewer Department ♦ Town of Longmeadow ♦ Lynnfield Water Department ♦ Lynn Water Commission ♦ Malden Public Works Department ◆ Marblehead Water and Sewer Department & Marlborough Public Works Department ♦ Massachusetts–American Water Company, Hingham ♦ Massachusetts Water Resources Authority, Boston & Medford Public Works Department & Melrose Water and Sewer Department ♦ Milton Public Works Department ♦ Nahant Water Department & Needham Department of Public Works ♦ Newton Water and Sewer Department ♦ Northborough Public Works Department . Norwood Public Works Department 

◆ Peady Water Treatment Plant 

◆ Quincy Public Works Department ♦ Revere Public Works Department ♦ Saugus Public Works Department & Somerville Water Department • Southborough Water Department • South Hadley Water Department ♦ Town of Southwick ♦ Springfield Municipal Water Department ♦ Stoneham Water Department • Swampscott Public Works Department ♦ Tighe & Bond Inc , Westfield ♦ Wakefield Public Works Department • Waltham Public Works Department • Watertown Public Works Department 

♦ Wellesley Water Department 

City of Westfield 

Weston Water Department **♦** Town of West Springfield **♦** Wilbraham Water Department **♦** Winchester Public Works Department **♦** Winthrop Water Department & Woburn Public Works Department & MICHIGAN: City of Adrian Water Department ◆ Allen Park Water Department 

◆ Ann Arbor Utilities 

◆ Ash Township Carleton ♦ Auburn Hills Water Department ♦ City

of Bay City Water Department • Belleville Water Department Brownstown Township Trenton ♦ Byron and Gaines Township, Grand Rapids ♦ Canton Township ♦ Centerline Water Department ♦ Chesterfield Water Department ♦ Clinton Township ♦ Commerce Township ♦ Dearborn Water Department ♦ Dearborn Heights Water Department ♦ City of Detroit Water and Sewerage Department . East Lansing Meridian Water Department, East Lansing 6 Eastpointe Water Department ♦ Ecorse Water Department ♦ Farmington Water Department ♦ Farmington Hills Water Department ♦ Ferndale Water Department ♦ Flat Rock Water Department ♦ Flint Water Department ♦ Fraser Water Department ♦ Garden City Water Department ♦ Georgetown Township, Jenison ♦ City of Grand Rapids ♦ City of Grandville Department ♦ Grosse Pointe Woods Water Department ♦ Hamtramck Water Department ♦ Harper Woods Water Department ♦ Harrison Township ♦ Hazel Park Water Department ♦ Holland Township ♦ City of Hudsonville ♦ Huron Township, New Boston 

 Inkster Water Department Keego Harbor Water Department ◆ City of Kentwood ◆ Lansing Board of Water and Light • Greater Lapeer County Utilities Authority, Lapeer ♦ Lenox Township ♦ Lincoln Park Water Department ♦ Livonia Water Department ♦ Macomb Township ♦ Madison Heights Water Department ♦ McNamee, Porter & Seeley, Inc , Detroit ♦ Melvindale Water Department 🌢 Midland Water Purification Plant 🜢 Michigan–American Water Company, Calumet ♦ Northville Water Department ♦ Northville Township ♦ Novi Water Department ♦ Oak Park Water Department ♦ Oakland County Drainage Commission, Pontiac 

Oakland County DPW, Pontiac • Olive Blendon Township Grand Haven ♦ Orion Township Water Department ♦ Plymouth Water Department ♦ Plymouth Township, Plymouth ♦ Pontiac Water Department ♦ PVS Technologies, Detroit ♦ Redford Township, Redford ♦ River Rouge Water Department ♦ Riverview Water Department • Rochester Hills Water Department 

Rockwood Water Department 

Village of Romeo Water Department • Romulus Water Department Roseville Water Department → Royal Oak Township, Ferndale ♦ Saginaw Department of Public Utilities ♦ Saginaw Midland Municipal Water Supply Corporation, Bay City 

Shelby Township 

Village of South Rockwood Water Department & Southeastern Oakland County Water Authority, Royal Oak ♦ Southgate Water Department ♦ Saint Clair Shores Water Department & Saint Clair County DPW, Port Huron ♦ Sterling Heights Water Department ♦ Sumpter Township, Belleville ♦ Sylvan Lake Water Department ♦ Taylor Water Department ♦ Trenton Water Department ◆ Troy Water Department ◆ Utica Water Department ◆ Van Buren Township, Belleville & Walled Lake Water Department, Led Lake ♦ Warren Water Department ♦ Washington Township ♦ Wayne Water Department ♦ West Bloomfield Township ♦ Westland Water Department ♦ Woodhaven Water Department • Wyoming Water Department, MINNESDTA: City of Arden Hills & City of Bloomington Utilities ♦ City of Brooklyn Park ♦ East Grand Forks Water and Light Department, East Grand Forks & Eden Prairie Water Supply ♦ EMA, Inc Saint Paul ♦ City of Falcon Heights ♦ City of Lauderdale ♦ City of Little Canada ♦ Mankato Municipal Water Supply 

◆ City of Maplewood ♦ City of Mendota Heights ♦ Minneapolis Water Works ♦ Rochester Public Utilities ♦ City of Roseville ♦ St Cloud Public Utilities • St. Paul Board of Water Commissioners Municipal Utility ♦ MISSOURI: Black & Veatch, Kansas City & Burns McDonnell Engineering, Inc Kansas City 

◆ Horner and Shifrin Inc , Saint Louis 

◆ City of Independence Water Department & Kansas City Water Department & Missouri-American Water Company & St Louis County Water Company & St Louis Water Division ♦ United Water Missouri Jefferson City ♦ MONTANA: Mountain Water Company Missoula ♦ NEBRASKA: Lincoln Water System Metropolitan Utilities District of Omaha ◆

NEVADA: Las Vegas Valley Water District ◆ Westpac Utilities, Reno . NEW HAMPSHIRE: ♦ Hampton Water Works Company ♦ Manchester Water Works 

◆ Salisbury Water Works Company, Hampton 

◆ NEW JERSEY: Bayonne Water Department ◆ Bloomfield Water Department 

Bloomingdale Board of Health ♦ Bloomingdale Water Department ♦ Brick Township Municipal Utilities Authority & Cedar Grove Board of Health **♦ Cedar Grove Water Department ♦ Consumers New Jersey** Water Company, Hamilton ♦ Township of East Brunswick ♦ Elizabethtown Water Company, Westfield ♦ Elmwood Park Board of Health & Elmwood Park Water Department & Fairfield Board of Health & Fairfield Water Department & Fair Lawn Board of Health ♦ Fair Lawn Water Department ▶ First Republic Corporation Board of Health, East Newark ▶ Garfield Board of Health & Garfield Water Department & Borough of Glen Ridge ♦ Haledon Board of Health ♦ Haledon Water Department 

Harrison Board of Health 

Harrison Water Department 

Hawthorne Board of Health 

Hea Hawthorne Water Department . Kearny Water Department **♦** Lincoln Park Board of Health **♦** Lincoln Park Water Department & Lodi Board of Health & Lodi Water Department 

Middlesex Water Company, Iselin 

Monroe Township Municipal Utilities Authority, Cranbury & Montclair Water Bureau & Mount Holly Water Company, Kenilworth ♦ New Jersey-American Water Company ♦ New Jersey Water Supply Authority, Clinton ♦ City of Newark ♦ NJAWC Board of Health, Little Falls & NJAWC Board of Health, West Orange 

♦ North Arlington Board of Health 

♦ North Arlington Water Department & North Caldwell Board of Health 

♦ North Caldwell Water Department 

♦ North Jersey District Water Supply Commission, Wanaque & Nutley Board of Health 

◆ Nutley Water Department 

◆ Passaic Valley Water Commission, Clifton ♦ Ringwood Board of Health **♦** Ringwood Water Department **♦** Riverdale Board of Company, Inc., Hazlet & Southeast Morris County MUA, Morristown & Southeast Morris County MUA Board of Health, Whippany ◆ Totowa Board of Health ◆ Totowa Water Department & Township of Sparta & Trenton Water Works ♦ United Water Lambertville ♦ United Water Mid-Atlantic, Mount Arlington & United Water New Jersey, Harrington Park & United Water Toms River & Wallington Board of Health & Wallington Water Department & Wanague Board of Health ♦ Wanague Water Department Washington Township MUA, Grenloch ◆ Wayne Township Division of Water & West Paterson Board of Health ♦ West Paterson Water Department ♦ **NEW** MEXICO: City of Albuquerque ◆ New Mexico-American Water Company, Clovis & Sangre De Cristo Water Company, Santa Fe & United Water New Mexico, Rio Rancho & NEW YORK: Alan Englander, Upper Nyack 

 Carle Place Water District 

 Dix Hills Water District, Huntington & Erie County Water Authority, Buffalo ♦ Village of Garden City ♦ General Chemical Corporation, Syracuse & Hazen and Sawyer, New York Hicksville Water Department Holzmacher McLendon & Murrel, Melville & Jamaica Water Supply Company, Lake Success & Latham Water District & Long Island Water Corporation, Lynbrook & Malcolm Pirme, Inc., White Plains **♦ Massapequa Water District ♦ Monroe County Water** Authority, Rochester & Mt Vernon Board of Water Supply New York-American Water Company, Greenwich ◆ New York City Department of Environmental Protection 

New York Water Service Corporation, Merrick 

♦ Oneonta Water District • Onondaga County Water Authority, Syracuse District & South Fai mingdale Water Department & United Water New Rochelle . United Water New York, West Nyack ♦ United Water Nichols, Owego ♦ United Water Owego & City of Utica Board of Water Supply & NORTH CAROLINA: Charlotte-Mecklenburg Utility Department, Charlotte & Durham Department of Water Resources ♦ Greenville Utilities Commission ♦ City of Jacksonville & Lexington Department of Water Resources & Orange Water & Sewer Authority, Carrboro . NORTH DAKUTA: City of Grand Forks Department of

Drinking Water ◆ □ HI□: Akron Public Utilities Bureau ▶ Bedford Water Department
 ▶ Cincinnati Water Works Cleveland Heights Water Department 

◆ City of Cleveland Division of Water ♦ Columbus Water Division ♦ Consumers Ohio Water Company, Boardman & Cuyahoga Falls Water Department ♦ Delphos Water Department ♦ East Cleveland Division of Water and Sewer ♦ City of Fostoria Water Department ♦ Lakewood Water- Wastewater Collection ♦ City of Lima Department of Utilities • Ohio-American Water Company 

◆ Price Brothers Company, Dayton 

◆ Toledo Division of Water ♦ □KLAH□MA: Oklahoma City Water Resources Administration ♦ Tulsa Water & Sewerage Department ◆ □REGON: City of Ashland Burlington Water District, Portland ◆ Clackamas Water District & Eugene Water and Electric Board & City of Water Company, Sandy ♦ City of Gresham ♦ Hideaway Hills Lorna Water Company, Portland 

♦ Lusted Water District, Gresham ♦ Medford Water Commission ♦ Mt Scott Water District, Portland & Oak Lodge Water District, Milwaukie & Palatine Hill Water District, Portland • Pleasant Home Water District, Gresham ♦ Portland Bureau of Water Works ▶ Powell Valley Water District, Portland ▶ Raleigh Water District, Portland 

◆ Rockwood Water District, Portland 

◆ Salem Public Works Department ♦ City of Tigard ♦ City of Tualatın • Tualatın Valley Water District, Beaverton • Valley View Water District, Portland ♦ West Slope Water District, Portland ♦ Westside Water Company, Tigard ♦ PENNSYLVANIA: Allentown Department Public Works-Bureau of Water ♦ Bucks County Water & Sewer Authority, Warrington ♦ Calgon Carbon Corporation, Pittsburgh 

Chester Water Authority 

Consumers' Pennsylvania Water Company, Sayre 

◆ Consumers' Pennsylvania Water Company, Shamokin & Consumers' Pennsylvania Water Company, Sharon • Dauphin Consolidated Water Company, Harrisburg & Gannett Fleming, Inc , Camp Hill ♦ L/B Water Service, Inc , Selinsgrove & Lehigh County Authority, Allentown ♦ Municipal Authority of the Borough of Oakmont ♦ Municipal Authority of Westmoreland County, Greensburg ♦ North Penn Water Authority, Lansdale ♦ North Wales Water Authority & Pennsylvania American Water Company, Hershey & Philadelphia Suburban Water Company, Bryn Mawr ♦ Philadelphia Water Department ♦ Pittsburgh Water Department ♦ Roberts Services, Inc , Darby ♦ Roy F Weston, Incorporated, West Chester ♦ Sear Brown Group, State College 

◆ Shenango Valley Water Company, Sharon 

◆ United Water Pennsylvania Bloomsburg Operation ♦ United Water Pennsylvania Dallas Operation & United Water Pennsylvania Harrisburg Operation . United Water Pennsylvania Mechanicsburg Operation & United Water Resources, Harrington Park & West Chester Area Municipal Authority WRc Engineers and Scientists, Huntingdon Valley 
 ♠ The York Water Company ◆ RHDDE ISLAND: Kingston Water District & Pawtucket Water Supply Board & Providence Water Supply Board 

◆ United Water Rhode Island, Wakefield • SOUTH CAROLINA: Beaufort-Jasper Water and Sewer Authority ♦ Charleston Commission of Public Works & Chester Metro Water Department ♦ Grand Strand Water & Sewer, Conway ♦ Greenville Water System • Mount Pleasant Water Works **♦** Summerville Commissioners of Public Works **♦ TENNESSEE:** Cleveland Utilities 

Duck River Utility Commission, Tullahoma ♦ City of Johnson City Division & Murfreesboro Water and Sewer Department ♦ Nashville Metro Department of Water & Sewer ♦ Tennessee–American Water Company, Chattanooga ♦ **TEXAS:** City of Abilene ◆ Alan Plummer & Associates, Inc , Arlington ♦ City of Allen ♦ City of Amarillo ♦ Arlington Water Utilities Department ♦ City of Austin Water & Wastewater Utility & Bacliff Municipal Utility District & Baybrook M U D #1 ♦ Baytown Area Water Authority Bethesda Water Supply Corporation, Burleson ♦ Brazos River Authority, Waco ♦ City of Burleson ♦ Cash Water Supply

Corporation, Greenville • Central Texas Water Supply Corporation, Harker Heights & Clear Lake Lity Water Authority, Houston & College Mound Water Supply Corporation, Terrell ♦ City of Crowley ♦ Dallas Water Utilities 

City of Dalworthington Gardens, Arlington 

■ Denton Municipal Utilities & Det 1, HSC/OEBW, Brooks Air Force Base ♦ DFW Airport ♦ East Fork Water Supply Corporation, Wylie ♦ City of Edgecliff Village ♦ El Paso Water Utilities 

City of Everman 

City of Fairview, McKinney 

City of Farmersville 

City of Fate 

City of Forest Hill ♦ City of Forney ♦ Forney Lake Water Supply Corporation, Rockwall & Fort Worth Water Department ♦ City of Friendswood
 ♦ City of Frisco
 ♦ City of Galveston WCID #12, Kemah ♦ City of Garland ♦ Gastonia-Scurry Water Supply Corporation, Scurry 

◆ Gulf Coast Water Authority, Texas City ♦ City of Haltom City ♦ Harris County M U D #55 

harris County M U D #192 

City of Haslet ♦ Houston Department of Public Works ♦ City of Hurst Water Department ♦ City of Irving ♦ City of Kaufman ♦ City of Keller 

City of La Marque 

Lakeshore Marina and RV Park, Graham ♦ City of Lake Worth ♦ City of LaPorte ♦ Laredo Water Works System 

▲ Lavon Water Supply Corporation ♦ City of League City ♦ City of Lucas ♦ City of Mansfield 

City of McKinney 

City of Mesquite 

City of Midland • Milligan Water Supply Corporation, McKinney Mount Zion Water Supply Corporation, Rockwall City of Murphy, Plano 

NASA Johnson Space Center, Houston 

City of Nassau Bay ♦ Nevada Water Supply Corporation ♦ City of North Richland Hills Water Department 

♦ North Texas Municipal Water District, Wylie 

◆ City of Parker 

◆ City of Pasadena Water Department ♦ City of Plano ♦ City of Princeton 

City of Richardson 

City of Richland Hills 

City of Roanoke ♦ City of Rockwall ♦ Rose Hill Water Supply Corporation, Kaufman ♦ City of Rowlett ♦ City of Royse City System 

◆ San Leon Municipal Utility District 

◆ City of Sansom Park ♦ Seis Lagos Municipal Utility District, Wylie City of South Houston City of Southlake City of Sunnyvale ♦ Tarrant County WC & I District #1, Ft Worth Tarrant Regional Water District, Fort Worth City of Texas City ♦Trinity River Authority, Arlington ♦ Trinity River Authority Grand Prairie, Arlington & Trinity River Authority Mosier Valley, Arlington 

◆ Trophy Club MUD #1 

◆ Uni Bell PVC Pipe Association, Dallas ♦ City of Waco Water Department • Weatherford Municipal Utilities System • City of Webster ♦ City of Westover Hills, Fort Worth ♦ Town of Westworth Village ♦ City of White Settlement ♦ City of Wylie Wylie Northeast Water Supply Corporation, Wylie ◆ LITAH: Central Utah Water Conservancy District, Orem 

 EIMCO Process Equipment Company, Salt Lake City Metropolitan Water District, Salt Lake City 
 ↑ The City of Provo 

Salt Lake City Public Utilities Department 

Salt Lake County Water Conservancy District, West Jordan . **VERMONT:** Champlain Water District, South Burlington ♦ VIRGINIA: Appointtox River Water Authority, Petersburg 

◆ Arlington County—Water, Sewer, and Streets Division & Blacksburg, Christianburg, VPI Water Authority, Blacksburg & Chesapeake Department of Public Utilities . Chesterfield County Department of Utilities . Clancy Environmental Consultants, Inc., St. Albans . Environmental Engineering & Technology, Inc., Newport News ♦ Fairfax County Water Authority, Merrifield ♦ Falls Church Department of Utilities 

◆ City of Fredericksburg **♦** Hagler Bailly Services, Arlington **♦** County of Henrico Virginia, Richmond ♦ Infilco Degremont, Incorporated, Richmond & Loudoun County Sanitation Authority, Leesburg ♦ Newport News Department of Public Utilities ♦ Norfolk Department of Utilities & Parsons Engineering Science, Inc., Fairfax & Prince William County Service Authority, Woodbridge 

◆ Richmond Department of Public Utilities 

◆ Rivanna Water & Sewer Authority, Charlottesville . Spotsylvania County-Ni River Water Plant ♦ United Water Virginia, Warsaw & Virginia-American Water Company, Alexandria & Virginia Beach Department of Public Utilities & Vista Consulting Group Inc., Arlington & WASHINGTON: City of Bellevue ♦ Economic and Engineering Services, Inc., Bellevue . Everett Water Department & Public Utility District #1 of Snohomish County, Everett ♦ City of Olympia ♦ Seattle Public Utilities **♦** Shoreline Water District, Seattle **♦** City of Spokane Water Department ♦ Tacoma Water Division ♦ Utility Services Associates, Seattle ♦ City of Walla Walla Water Division ♦ WEST VIRGINIA: Morgantown Utility Board ♦ West Virginia-American Water Company, Charleston ♦ West Virginia-American Water Company, Huntington 6 WISCONSIN: Badger Meter, Inc., Milwaukee ♦ Bonestroo, Rosene, Anderlik & Associates, Inc., Mequon Green Bay Water Utility 

◆ The Kjell Corporation, Beloit 

◆ Kenosha Water Utility ♦ Madison Water Utility ♦ Manitowoc Public Utilities . Milwaukee Water Works . North Shore Water Commission, Milwaukee 

◆ Oak Creek Water and Sewer Utility ♦ Racine Water Department ♦ Stevens Point Water Department & Wausau Water Utility & Wauwatosa Water Utility ◆ WY□MING: City of Laramie Water Department & Shoshone Municipal Pipeline, Cody & **CANADA:** ADI Group, Inc ◆ Associated Engineering (AB) Ltd., Edmonton, Alberta & Aqualta, Alberta & The Corporation of the City of Brantford, Ontario . Buffalo Pound Water Administration Board, Saskatchewan Regional District Water Department, British Columbia . Capital Region Parkland Water Services, Alberta 6 Charlottetown Water Commission, Prince Edward Island 6 Dayton & Knight Ltd., West Vancouver, British Columbia Regional District, British Columbia & City of Fredericton Water and Sewer, New Brunswick & Greater Vancouver Regional District, British Columbia & Halifax Water Commission, Nova Scotia & Kingston Public Utilities Commission, Ontario 

◆ City of Laval, Quebec 

◆ Moosehead Breweries Limited, Saint John, New Brunswick & Municipality of Metropolitan Toronto, Ontario & National Research Council of Canada, Ontario . Town of New Glasgow, Nova Scotia & NWW Canada Ltd , Toronto, Ontario ♦ Peterborough Utilities Commission, Ontario ♦ Proctor & Redfern Limited, Don Mills, Ontario & City of Regina, Saskatchewan ♦ Regional Municipality of Ottawa-Carleton,

Ontario . Regional Municipality of Waterloo, Ontario . Saint John Water & Sewer Dept , New Brunswick . Scarborough Public Utilities Commission, Ontario & City of Toronto Dept of Public Works, Ontario ♦ Windsor Utilities Commission, Ontario ♦ City of Winnipeg, Manitoba ♦ EUROPE: Anghan Water Services Ltd., Cambridge, England 

♦ Vivendi, France (Metcalf & Eddy) 

♦ Essex and Suffolk Water Plc, Essex, England & GU Partnership, Herts, United Kingdom 

♦ Lyonnaise des Eaux, Paris, France ♦ Severn Trent Water Limited, Birmingham, England ♦ Thames Water Plc, Middlesex, England & United Utilities Plc, Warrington, England ♦ X-Flow B V, the Netherlands ♦ Yorkshire Water Plc, Bradford, England & Water & Environmental Technology Team, Czech Republic . AUSTRALIA: Australian Water Quality Centre, Bolivar, South Australia ♦ Sydney Water Board ♦ NEW ZEALAND: Southpark Property Services, Penrose, Auckland •

September 30, 1998

### AWWARF'S RESEARCH PARTNERS

In addition to working with its subscribers, the AWWA Research Foundation maintains ongoing research partnerships with a wide variety of organizations. The purpose of such partnerships is to cooperatively leverage limited research dollars on a topic of common interest. These partnerships can take various forms, including joint funding of projects or co-authoring state-of-the-science reports. The following nonsubscribing organizations are AWWARF's research partners:

American Water Works Association (AWWA) ♠ Arsenic Research Partnership (AsRP is funded by the Association of California Water Agencies, USEPA, and AWWARF) ♠ California Energy Commission ♠ Electric Power Research Institute (EPRI) ♠ Electric Power Research Institute (EPRI) ♠ Electric Power Research Institute (Community Environment Center (EPRI CEC) ♠ German Union of Gas- and Waterworks (DVGW) ♠ Florida Deptartment of Envronmental Protection ♠ Florida Department of Health ♠ International Life Sciences Institute (ILSI) ♠ International Water Supply Association (IWSA) ♠ Japan Water Works

Association ♠ Kiwa N V (a water research organization in the Netherlands) ♠ Lawrence Livermore National Laboratory (LLNL) ♠ Los Angeles County Sanitation Districts (LACSD) ♠ Microbial/ Disinfectant By-products Council (the M/DBP Council is funded by AWWARF and USEPA and includes representatives from AWWARF, USEPA, and other parties to the regulation—negotiation process) ♠ Missouri River Public Water Supphes Association ♠ National Academy of Sciences (NAS) ♠ National Water Research Institute (NWRI) ♠ New York Power Authority ♠ New York State Energy Research ♠

Southern California Edison ♦ South Florida Water
Management District ♦ Subregional Operating Group (SROG)
of the Phoenix (Ariz ) Valley ♦ U S Bureau of Reclamation
♦ U.S Environmental Protection Agency (USEPA) ♦ Union
Electric ♦ United Kingdom Drinking Water Inspectorate
(UKDWI) ♦ United Kingdom Water Industry Research Ltd
(UKWIR) ♦ United Water International, Pty Ltd ♦ Water
Environment Research Foundation (WERF) ♦ Water Research
Commission of South Africa ♦

<b>THE 1998</b>
<b>PROJECT</b>
<b>SUMMARY</b>
BOOK

A Summary of AWWA Research Foundation Projects



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#### INTRODUCTION

The AWWA Research Foundation was created by the water supply community as its center for cooperative research and development. The foundation functions as a planning and management agency, awarding research contracts to water utilities, universities, engineering firms, and other organizations. The scientific and technical expertise of the foundation staff is enhanced by industry volunteers who serve on Project Advisory Committees and on other standing committees and councils. An extensive planning process involves many hundreds of water industry professionals in the important task of keeping the foundation's program responsive to the practical, operational needs of local utilities and to the general research and development needs of a progressive industry.

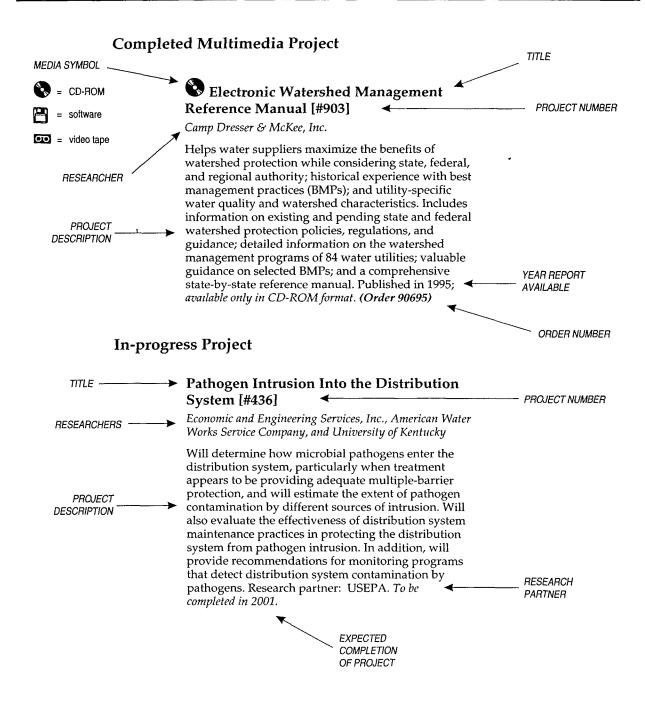
The foundation's research agenda embraces all aspects of water supply: resources; treatment and operations; distribution and storage; water quality and analysis; health effects; and, economics and management. The ultimate purpose of the foundation's efforts is to assist local water purveyors in their efforts to deliver a reliable and economical supply of the highest possible quality drinking water.

This publication summarizes all the completed and ongoing research projects sponsored by the foundation. Project descriptions include names of contractors. Descriptions of completed projects include numbers for ordering final reports. More information on specific projects can be obtained by contacting:

Deborah R. Brink
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#### SAMPLE PROJECT DESCRIPTIONS



Research Foundation Subscribers can order completed reports by writing to AWWARF, 6666 West Quincy Avenue, Denver, CO 80235; by calling (303) 347-6121, by sending a fax to (303) 730-0851; or by sending an e-mail message to rfreports@awwarf.com Others, including AWWA members, can purchase reports from the AWWA Bookstore by calling (800) 926-7337 Please note that nonsubscribers can only order reports for completed projects that have order numbers.

#### WATER RESOURCES

#### **Water Quality**

## Aquifer Storage Recovery of Drinking Water From the Cambrian-Ordovician Aquifer in Wisconsin [#2539]

CH2M Hill

Will determine the feasibility and suitability of the Cambrian-Ordovician aquifer for storage and recovery of treated water from Lake Michigan. Will provide data that will improve the ability to predict plugging rates and, therefore, improve design and operation of ASR facilities using this aquifer, which underlies a major portion of the midwestern United States. Research partner: Oak Creek Water and Sewer Utility, Wis. *To be completed in 2001*.

#### Biology and Potential Impacts of Zebra Mussels in Large Rivers [#733]

University of Louisville

Evaluates the survival, growth, and reproduction of the zebra mussel, *Dreissena polymorpha*, and the quagga mussel, *D. bugensis*, in riverine mesocosms using untreated, flowing river water. Also examines the seasonal effects of elevated temperatures and the influence of current velocity. Helps predict the ecological success of *Dreissena polymorpha* in large river ecosystems, and thus their potential impact on water utilities. Also monitors the population dynamics of zebra mussels within the Ohio River. Published in 1997. (*Order 90724*)

#### Controlling Zebra Mussels at Water Treatment Plant Intakes [#614]

City of Toledo (Ohio)

Evaluates the effectiveness and costs of chemical treatments on zebra mussel veliger inactivation and veliger mortality. Reports on studies of sodium hypochlorite, iron plus hydrogen peroxide, potassium permanganate, chlorine dioxide, chloramine, and ammonium at two Lake Erie sites. Published in 1997. (Order 90612)

#### Controlling Zebra Mussels at Water Treatment Plant Intakes II [#821]

City of Toledo (Ohio)

Investigates operational aspects likely to be affected by zebra mussel infestation. Studies distribution of pipe infestation, pipe interior roughness changes and hydraulic impacts, and waste material handling. Also evaluates sodium hypochlorite, potassium permanganate, chlorine dioxide, and chloramine for preventing mussel settlement. Research partner: USEPA. Completed in 1998. *A report is available only to AWWARF subscribers*.

## *Cryptosporidium* Inactivation in Natural Waters [#375]

Montgomery Watson

Will create a database of appropriate disinfection strategies and design criteria for each of the project participants. Will statistically analyze the database to draw more universal conclusions about the inactivation of the organism. Will also provide a better understanding of the effect of water quality on disinfection of *Cryptosporidium*. Research partner: Kiwa N.V. *To be completed in 1999*.

## Current Methodology for the Control of Algae in Surface Reservoirs [#53]

Casitas (Calif.) Municipal Water District

Identifies and documents physical and chemical technologies for controlling algae in drinking water reservoirs, with particular emphasis on copper. Published in 1987. (Out of print)

## Cyanobacterial (Blue-Green Algal) Toxins: A Resource Guide [#925]

Summarizes international experiences with algal toxins into a comprehensive resource document for water utilities. Includes chapters on the production of toxins, health effects and risk assessment, monitoring and analysis, control of blooms, water treatment methods, management and contingency planning, and public information. Also provides examples of public information brochures and fact sheets. Published in 1995. (*Order* 90693)

## Cyst and Oocyst Survival in Watersheds and Factors Affecting Inactivation [#151]

University of Ottawa and American Water Works Service Company

Will evaluate the survival of *Cryptosporidium* oocysts and *Giardia* cysts exposed to differing environmental conditions and determine subsequent effects on disinfection efficiency. Will study effects of temperature, age, and physical stress on viability and susceptibility to disinfection. *To be published in 1999*.

## Determining Groundwater Under the Direct Influence of Surface Water [#605]

State University of New York Research Foundation

Presents approaches for evaluating groundwaters to assist water source assessors in determining the origin of a drinking water source. The project was completed in 1996, and *a report is available upon request*.

## Effective Watershed Management for Surface Water Supplies [#317]

Portland (Ore.) Bureau of Water Works

Examines which watershed management practices best protect raw water supplies and documents installation, operation, and management costs of those judged technically and economically feasible for controlling THM precursors, general organics, iron, manganese, dissolved gases, algae, and algae nutrients. Also includes guidelines to help utility managers make watershed management decisions. Published in 1991. (Out of print)

#### Effluent Trading [#471]

Brown and Caldwell

Will characterize watershed-based effluent trading scenarios, with an emphasis on evaluation of effects on source water quality. Will also evaluate both the positive and negative aspects of trading. Research partner: WERF. *To be completed in 2000.* 

## Electronic Watershed Management Reference Manual [#903]

Camp Dresser & McKee, Inc.

Helps water suppliers maximize the benefits of watershed protection while considering state, federal, and regional authority; historical experience with best management practices (BMPs); and utility-specific water quality and watershed characteristics. Includes information on existing and pending state and federal watershed protection policies, regulations, and guidance; detailed information on the watershed management programs of 84 water utilities; valuable guidance on selected BMPs; and a comprehensive state-by-state reference manual. Published in 1995; available only in CD-ROM format. (Out of print)

### Evaluation of Sources of Pathogens and NOM in Watersheds [#251]

Stroud Water Research Center, Wisconsin State Laboratory of Hygiene, and South Central Connecticut Regional Water Authority (New Haven)

Will determine the distribution and densities of *Giardia* and *Cryptosporidium* and the concentrations of NOM in watersheds, and evaluate potential sources in field studies. Will develop potential source control strategies

that will mitigate the concentrations of these contaminants in influent water resulting in potential treatment savings. *To be completed in 1999*.

#### Feasibility Analysis and Design of Research to Evaluate Microbiological Constituents and Treatability in Source Waters [#385]

Hagler Bailly Consulting, Inc., and Technology Planning and Management Corporation

Will examine the state of knowledge regarding the presence and treatability of microbial constituents in source waters. Based on available information, will identify those highest priority data needs related to creation of technically justified monitoring requirements under the Enhanced Surface Water Treatment Rule. Will create an experimental design(s) for follow-on studies to generate those data that are most needed. Research partner: M/DBP Council. *To be completed in 1999*.

#### Field Study of Virus and Indicator Transport to Support the GWDR "Natural Disinfection" Criteria [#262]

University of California at Riverside, U.S. Salinity Laboratory, State of Florida Dept. of Health and Rehabilitative Services, University of Arizona, and University of South Florida

Will develop a scientific basis for "natural disinfection" criteria in the Ground Water Disinfection Rule (GWDR). Will assess the potential for developing indicators of viral contamination of groundwater and will obtain data that can be used to test the virus transport model used in the development of the existing numerical values for the proposed "natural disinfection" criteria. To be completed in 1999.

### Identification and Control of Odorous Algal Metabolites [#716]

Virginia Polytechnic Institute and State University

Identifies producers of taste and odor compounds. Also determines the stages of the algae's life cycle that are principal for the production and release of the taste and odor compounds, and identifies treatment alternatives that can alleviate the biological contribution to taste and odor problems. Published in 1996. (Out of print)

## Inactivation Rates of Viruses and Bacteria in Saturated and Unsaturated Subsurface Media [#353]

University of Delaware and University of California at Riverside

Will determine the inactivation rates of pathogenic human enteric viruses, bacteria, and bacteriophages in saturated and unsaturated soils and aquifer materials under a variety of environmental conditions (e.g., temperature, pH, moisture content, etc.). Will also

determine the critical soil factors that influence the survival of pathogenic microorganisms in the subsurface media. Will discuss the significance of the results to "natural disinfection" in relation to the Ground Water Disinfection Rule and to utility groundwater management efforts. To be completed in 1999.

## Isotopic Tracers of Nonpoint-Source Pollution in Surface Waters [#376]

Lawrence Livermore National Laboratory

Will evaluate isotope measurements for determining sources of nonpoint-source pollution in surface water Will determine if these measurements can be coupled with natural organic matter characterization and trace element concentrations to better pinpoint nonpoint sources. Will also determine if these data delineate mechanisms of the fate and transport of aquatic nutrients and contaminants in surface water. Will evaluate if these data can be used effectively and economically to predict drinking water quality and to improve decision making for land use adjacent to surface water resources. Research partner. Lawrence Livermore National Laboratory. To be completed in 1999.

#### Methods for Monitoring Iron and Manganese Biofouling in Water Wells [#535]

S A Smith Consulting Services and Ohio State University

Offers practical methods of monitoring biofilm growth associated with iron- and manganese-utilizing bacteria in new and rehabilitated wells. Presents laboratory and field evaluations at three dissimilar wellfields. Also provides practical recommendations for monitoring biofouling that are suitable for widespread water industry use. Published in 1992. (Out of print)

## Microbial Source Tracking: Feasibility of a National Database [#556]

University of Washington

Will demonstrate the utility of the Microbial Source Tracking method to identify sources of microbial pollution in watershed and source waters. Will also test the feasibility of using a database of source-specific genetic fingerprints of *E. coli* to identify sources of fecal pollution in geographic regions not represented in the database. *To be completed in 2000*.

## Model for Trihalomethane Precursors in Lakes and Rivers [#557]

Up-tate Freshwater Institute (Syracuse, N Y ) and Michigan Technological University

Will quantify the relative contributions of external and internal sources to the THM precursor pools of five water supply reservoirs. Will identify, characterize, and

quantify the sources and sinks of precursors in reservoirs. Will also develop and test a mechanistic model capable of simulating the magnitude and dynamics of the precursor pool in a single productive water supply reservoir. To be completed in 2000.

#### Modeling Water Conservation [#737]

Powell Consortium Member Institutes

Assesses the impact of price and non-price variables upon municipal water consumption. Presents a model of municipal consumption and statistically compares data from several metropolitan areas. Provides recommendations for municipal conservation programs designed to reduce summer exterior use, respond to acute drought or water supply shortage, and stimulate long-term efficient use of municipal water. To be published in late 1998 as two reports. Effectiveness of Residential Water Conservation Price and Non-price Programs (90747) and Residential Water Use, Rate, Revenue and Non-price Conservation Program Database (90748).

## National Assessment of MTBE Occurrence in Drinking Water [#2507]

Metropolitan Water District of Southern California (Los Angeles) and U S Geological Survey

Will develop a representational national database of MTBE concentrations in both groundwater and surface water supplies *To be completed in 2001*.

### National Assessment of Perchlorate Contamination Occurrence [#2508]

Metropolitan Water District of Southern California (Los Angeles) and Montgomery Watson

Will identify areas across the United States at high potential for environmental perchlorate contamination, and rank the likelihood of the presence of perchlorate contamination in a water utility source water Will conduct targeted sampling at those utilities most likely to be impacted by perchlorate contamination *To be completed in 2001.* 

#### Predicting Water Quality Changes From Artificial Recharge Sources to Nearby Wellfields [#486]

Alameda County (Calif ) Water District and Lawrence Livermore National Laboratory

Will quantify water quality changes that take place during transit from surface water recharge points to groundwater production wells supplying drinking water Will use state-of-the-art isotope tracer techniques combined with low-level organic and inorganic analyses and pathogen monitoring Research partner Alameda County Water District *To be completed in 1999*.

## Reservoir Management for Water Quality and THM Precursor Control [#308]

Kent State University

Describes reservoir management techniques for maintaining or improving the quality of water supply resources, especially those techniques shown to be successful in field-scale applications. Quantifies each technique's degree of success with respect to raw water levels of THM precursors, iron, manganese, dissolved gases, algae, and general organic matter. Also evaluates techniques with respect to cost–benefit ratios, and documents successful applications. Published in 1989. (Out of print)

#### Source Water Variability Assessment [#488]

American Water Works Service Company, Clancy Environmental Consultants, Technology Planning & Management Corporation, and Hagler Bailly Services, Inc.

Will determine watershed processes and characteristics that influence pathogen loading at water treatment plants. Will also estimate resulting extreme and average pathogen concentrations. Research partner: M/DBP Council. *To be completed in 2001*.

### Surface Water Screening Model—A Case Study for Water Utility Management [#66]

Grayman Consulting Engineers, GKY Associates, and New Orleans (La.) Sewerage and Water Board

Examines the predictability of water quality at river intakes using computer models to evaluate data related to upstream industrial discharges and streamflow. Shows how analysis of existing upstream discharge data can help water utilities better understand when water quality changes will occur, thereby facilitating maintenance of optimum treatment process removal efficiencies. Published in 1987. (Out of print)

## Use of Constructed Wetlands for Protection of Water Quality in Water Supply Reservoirs [#807]

Tarrant County Water Control and Improvement District Number One (Fort Worth, Texas) and Alan Plummer & Associates, Inc.

Evaluates construction and operation of a wetland pilot facility to determine the impact of the wetland system on overall reservoir water quality. Provides cost data for the construction and maintenance of the wetland facility. Also includes a cost–benefit ratio to determine the impacts of the constructed wetland treatment on subsequent treatment processes for reservoir management. Published in 1996. Research partner: USEPA. (Order 90696)

## Water Quality Impacts From Blending Multiple Water Types [#469]

Laboratory of the Government Chemist (U.K.) and Pipeline Development Ltd.

Will examine the effects on water quality and distribution systems that result from mixing or blending finished waters of differing quality. Also will develop guidance for avoiding water quality deterioration when blending occurs. To be completed in 2000.

#### **Water Quantity**

## Aquifer Storage Recovery of Treated Drinking Water [#713]

CH2M Hill

Identifies changes in water quality occurring during aquifer storage. Also evaluates the relationship between the rate of particulate plugging of wells and such factors as recharge water quality, flow rate, redevelopment frequency, and aquifer permeability. Provides a set of criteria for aquifer storage recovery (ASR) applicability throughout North America, as well as a discussion of pertinent issues to ASR such as cost-effectiveness and regulatory issues. In addition, uses available data to calibrate a hydrogeologic model to simulate mixing between stored and native water. Published in 1996. (Order 90689)

### Augmenting Potable Water Supplies With Reclaimed Water [#371]

National Research Council

Gives technical guidance regarding the use of treated municipal wastewater as a potable water source. Provides regulators and utilities with guidance to assess the feasibility and desirability of potable reuse projects as a means of supplementing water supplies. Includes recommendations for future research. Research partner: NAS. AWWARF will not publish a final report. However, the NRC published this work in 1998 as Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies With Reclaimed Water (ISBN 0-309-06416-3). This report is available from the National Academy Press (telephone: 1-800-624-6242; website: http://www.nap.edu/bookstore).

#### Identification of Factors That Constrain the Development of Water Supplies to Meet Future Demands [#343]

Economic and Engineering Services, Inc., Black & Veatch, and Colorado State University

Will provide information and guidance to utility managers regarding national regulatory constraints to development and reservation of water resources for the purpose of meeting long-term (e.g., 50- to 100-year) future demands for potable water. *To be completed in* **2000.** 

## Impacts of Demand Reduction on Water Utilities [#838]

Montgomery Watson

Provides utility managers with data to accurately quantify the impacts of reduced flows resulting from conservation measures and to evaluate the impacts on operating costs. Also assists water planners in implementing a least-cost-facility expansion or upgrade policy and in integrating conservation measures during the master planning process. Published in 1996. (*Order 90690*)

## Investigation of Soil-Aquifer Treatment for Sustainable Water Reuse [#487]

Arizona State University

Will establish the efficacy and sustainability of wetlands and soil-aquifer treatments leading to indirect potable water reuse. Will generate practical tools with which to assess water quality and to gauge compliance with regulatory reuse criteria. Research partners: SROG and LACSD. To be completed in 2000.

## Long-Term Effects of Conservation Rates [#902]

Wade Miller Associates, Inc.

Provides guidance on an overview analysis of the long-term effects of conservation pricing strategies. Includes a computer-based spreadsheet forecasting model for evaluating conservation rates. Published in 1997. (Order 90723)

## Managing the Revenue and Cash Flow Effects of Conservation [#840]

Wade Miller Associates, Inc.

Provides guidelines and mechanisms to help utility managers forecast and analyze revenue and cash flow impacts from conservation programs. Published in 1996. (Out of print)

#### Residential End Uses of Water [#241]

Aquacraft, Inc., Planning and Management Consultants Ltd., and Water Resources Management

Will provide specific data on the end uses of water in residential, commercial, and institutional settings across the United States. Will include data on disaggregated indoor and outdoor uses. Will use data to improve engineering estimates of residential, commercial, and institutional water consumption. Research partner: U.S. Bureau of Reclamation. *To be completed in 1999.* 

## Revenue Instability and Conservation Rate Structures [#839]

A & N Technical Services, Inc.

Provides empirical models to predict the distribution of water demand and future revenue to utilities. Improves quantitative prediction tools by examining agencies' experience with conservation rate structures. Published in 1995. (Out of print)

#### Socioeconomic Impacts of Conservation [#497]

A & N Technical Services, Inc.

Will determine the economic impact of different types of conservation programs on low-income customers. Will also determine the subsequent impact on the financial integrity of utilities, as well as the overall impact on other utility services. *To be completed in* 2001.

## Soil Treatability Pilot Studies to Design and Model Soil Aquifer Treatment Systems [#901]

Arizona State University, University of Arizona, University of Colorado, U.S. Water Conservation Laboratory, and Greeley and Hanson

Describes a comprehensive study on soil aquifer treatment (SAT) to develop correlations between soil characteristics, effluent types, infiltration rates, and SAT efficiencies. Evaluates treatment efficiencies and removal mechanisms for a variety of common soils and effluents in SAT pilot studies. Presents an optimal SAT design methodology and an operational optimization model for application to multi-basin SAT systems. Research partners: WERF, NWRI, and SROG. Published in 1998. (Order 90731)

#### WaterPlan Version 2.0 [#634]

Synergic Resources Corporation

Revises a California Department of Water Resources guidebook and software program originally developed for California municipal planners in estimating the cost, benefits, and savings of urban water conservation programs. Makes the software program applicable throughout the United States and more user friendly. Published in 1996. (Order 53040)

#### Water Management

## Comparing Basins, Galleries, and Shallow Wells for the Recharge of a Deep Aquifer [#2529]

To be determined

Will compare and determine the feasibility of three different methods of aquifer recharge for an aquifer system where depth of the water table is over 350 feet and suitable storage volume is available. Research partner: El Paso Water Utilities. *To be completed in* 2001.

### Evaluation and Restoration of Water Supply Wells [#401]

National Ground Water Association

Examines the causes for decreases in water well productivity. Describes the advantages and disadvantages of available well restoration practices. Also develops guidance on procedures to determine reasons for reduced productivity and on cost of restoration. Published in 1993. (*Order* 90598)

## Field Transport of *Cryptosporidium* in Small Catchments Used for Grazing Lands [#2566]

Georgia Institute of Technology

Will study the natural movement of colloidal-sized particles such as *Cryptosporidium* at an undisturbed field site used for cattle production. Will also improve approaches to modeling oocyst transport in unsaturated soils using existing water flow and transport models. *To be completed in 2001.* 

### Guidance to Utilities: Building Alliances With Watershed Stakeholders [#468]

Hagler Bailly Consulting, Inc., Tellus Institute, Technology Planning & Management Corporation, Robert Hurd & Associates, and Katz & Associates

Will identify typical watershed stakeholders and their objectives in basin planning. Also, will develop procedures for building win-win alliances between water utilities and stakeholders for the purpose of overcoming constraints to planning, managing, and developing long-term (50- to 100-year) sustainable drinking water supplies. To be completed in 1999.

#### Guidelines for Implementing an Effective Integrated Resources Planning Process [#920]

Wade Miller Associates, Inc., West Virginia University, and Tellus Institute

Describes successful methods of conducting and implementing integrated resources planning (IRP), a comprehensive water resource planning technique. Includes conceptual and working definitions of IRP and, through case studies, shows elements of successful methods used to achieve consensus and to acquire regulatory approvals and public acceptance. Published in 1996. (Order 90718)

## Hollywood (Fla.) Aquifer Reclamation Project [#485]

City of Hollywood (Fla.) Public Utilities

Will determine whether the injection of highly treated wastewater effluent controls saltwater intrusion of the regions' sole-source aquifer. Research partner: Hollywood (Fla.) Public Utilities Administration. *To be completed in 2000*.

## Investigation of Criteria for Groundwater Under Direct Influence [#2538]

Montgomery Watson

Will gather and evaluate data to assist in determining GWUDI for the unique characteristics associated with limestone aquifers. Will investigate the concept of natural filtration and evaluate the importance of average travel time for protection against GWUDI. Will develop a protocol defining the specific methodology for making a GWUDI determination. Research partners: Miami–Dade Water and Sewer Department, Palm Beach County (Fla.) Public Utilities Dept., South Florida Water Management District, City of Ft. Lauderdale (Fla.) Public Services Dept., City of Hollywood (Fla.), Florida Dept. of Environmental Protection, Florida Dept. of Health, and Broward County (Fla.) Office of Environmental Services. To be completed in 2001.

#### Well Condition Assessment and Rehabilitation Techniques for Meeting Output and Quality Goals [#464]

Leggette, Brashears & Graham, Inc., and Droycon Bioconcepts, Inc.

Will test and compare various techniques for well rehabilitation. Will emphasize new chemical treatment techniques and possible adaptations of technologies from other industries. *To be completed in 2000.* 

#### WATER TREATMENT

#### Chemical Processes for Microbial, Organic, and Disinfection By-product (DBP) Control

#### Advanced Oxidation and Biodegradation Processes for the Destruction of TOC and DBP Precursors [#289]

University of Texas at Austin and University of Houston

Studies the effect of advanced oxidation by ozone-hydrogen peroxide and UV-hydrogen peroxide in combination with biodegradation on destroying TOC and reducing DBP precursors. Tests water from two dissimilar surface sources with a wide range of oxidation conditions followed by complete biodegradation. Uses TOC, UV absorbance, and halogenated DBP precursor removal to measure treatment performance. To be published in late 1998. (Order 90758)

## Alternative Disinfection Technologies for Small Drinking Water Systems [#621]

Process Applications, Inc.

Summarizes the design requirements for the application of ozone, chlorine dioxide, and UV radiation for disinfection of small systems (pop. 1,000–10,000). Published in 1992. (Out of print)

#### Bromate Formation and Control During Ozonation of Low Bromide Waters [#493]

Montgomery Watson

Will evaluate the formation and control of bromate in low bromide waters under ozone dosages capable of inactivating *Cryptosporidium*. Research partner: M/DBP Council. *To be completed in 2001*.

## Case Studies of Modifications of Treatment Practices to Meet the New D/DBP Regulation [#369]

Metropolitan Water District of Southern California (Los Angeles), Malcolm Pirnie, Inc., and Apogee Research, Inc.

Will conduct case studies at 10–15 utilities that have implemented treatment modifications to comply with the proposed Disinfectants/Disinfection By-Products (D/DBP) Rule and Enhanced Surface Water Treatment Rule. Will document the modifications made, the associated costs, and the lessons learned through implementation. *To be completed in 1999*.

## Case Studies of Modified Disinfection Practices for Trihalomethane Control [#201]

Tennessee Technological University

Provides guidance on disinfection practices for water system designers and operators, based on a review of experiences and practices of systems that have changed treatment processes to comply with regulations or for other reasons. Describes problems encountered, additional costs or savings, water quality changes, and other operational and management areas affected by treatment changes. Published in 1990. (Out of print)

## Chlorination By-products: Production and Control [#224]

The Netherlands Waterworks Testing and Research Institute (KIWA)

Reports on the research results and operational experiences in The Netherlands with respect to the measurement and control of disinfection by-products, particularly THMs. Serves as a practical resource of technical information for operators, engineers, and managers. Published in 1986. (Out of print)

## Chlorine Dioxide: Drinking Water Issues [no #]

Presents papers from a 1992 symposium to assess the advantages and disadvantages of chlorine dioxide as a water treatment tool. The symposium co-sponsors were the Chemical Manufacturers Association, the AWWA Research Foundation, and USEPA. Published in 1993. (Out of print)

#### Chloro-Organic Water Quality Changes Resulting From Modification of Water Treatment Practices [#76]

Louisville (Ky.) Water Company and University of Louisville

Assesses effects of changing water treatment practices to meet more stringent THM regulations on overall THM and TOX levels in finished water, based on data collected from six U.S. utilities and a pilot plant. Also identifies treatment practices that minimize THM and TOX levels. Published in 1987. (Out of print)

#### Demonstration-Scale Evaluation of Engineering Aspects of the PEROXONE Advanced Oxidation Process [#525]

Metropolitan Water District of Southern California (Los Angeles) and Montgomery Watson

Will evaluate ozone and PEROXONE (ozone in combination with hydrogen peroxide) processes to confirm pilot-plant results for taste and odor control, disinfection by-product control, disinfection, and turbidity removal. Will also determine mass transfer efficiencies of the processes and evaluate various process considerations and equipment alternatives. To be completed in 1998.

#### Destruction of Disinfection By-product Precursors Using Photoassisted Heterogeneous Catalytic Oxidation [#511]

Michigan Technological University

Investigates two aqueous oxidation technologies, advanced photocatalytic oxidation and phase-transfer catalysis, for the removal of disinfection by-product (DBP) precursors. Shows that while phase-transfer catalysis is effective for the removal of specific organic compounds, photocatalytic oxidation is more effective for DBP precursor removal. Also estimates the cost and determines the rate and degree of destruction of DBP precursors. Published in 1993. (Out of print)

## Development and Validation of Rational Design Methods of Disinfection [#702]

Drexel University, Montgomery Watson, and Portland (Ore.) Bureau of Water Works

Develops a protocol and a model to improve prediction of full-scale disinfection performance. Also evaluates the impact of disinfectant dose and contact time on the inactivation of Escherichia coli, Giardia muris, and bacteriophage MS2. Studies oxidants such as chlorine, chloramines, and ozone. Published in two reports: Experimental Methodologies for the Determination of Disinfection Effectiveness (Out of print) was published in 1993. Development and Validation of Rational Design Methods of Disinfection (Out of print) was published in 1995.

#### Development of an Implementation Protocol for the Integrated Disinfection Design Framework [#472]

CH2M Hill

Will develop a protocol for implementing the Integrated Disinfection Design Framework that could be used by utilities and regulators as the basis for developing disinfection design, operating criteria, and regulatory requirements for site-specific prediction of the amount of disinfection needed. To be completed in 2001.

#### Disinfection Efficiency and Dose Measurement for Medium Pressure and Pulsed-UV Disinfection Systems [#2559]

University of North Carolina at Charlotte

Will compare UV dose measurement methodologies and evaluate the disinfection effectiveness of high intensity polychromatic UV radiation from medium pressure and pulsed UV disinfection systems. Will also provide information on UV dose/log inactivation for selected organisms. *To be completed in 2001*.

#### A Dynamic System to Study the Influence of Biologicals, Chemicals, and Particulates on the Disinfection of Drinking Water [#551]

University of Ottawa

Will develop a model of disinfectant-microbe interactions in flowing water systems and use it to examine the relative disinfectant efficacies among organisms subjected to different water quality conditions. Will investigate the influence of a variety of water quality parameters, including inorganic or organic turbidity and dissolved organic carbon, in protecting microbial populations from disinfectant action. To be completed in 2000.

#### The Effect of Bicarbonate Alkalinity on the Performance of Advanced Oxidation Processes [#533]

Illinois State Water Survey

Evaluates the dominance of carbonate radical anion (CAB) versus the hydroxyl radical in the application of advanced oxidation processes (AOP) to waters high in carbonate/bicarbonate alkalinity. Provides a better understanding of the effect of CAB on specific organics and oxidation by-products, promoting optimal use of AOP for maximum treatment efficiencies. Published in 1998. (Order 90737)

## Effect of Various Disinfection Methods on the Inactivation of *Cryptosporidium* [#906]

University of Alberta

Investigates the effectiveness of ozone, potassium permanganate, chlorine, chlorine dioxide, and ultraviolet radiation (UV) on inactivation of *Cryptosporidium*. Also investigates the use of combinations of disinfectants such as ozone–UV and ozone with hydrogen peroxide. Research partner: USEPA. Published in 1998. (*Order 90734*)

## Effects of Preoxidation With Ozone on Water Quality: A Case Study [#75]

City of Bay City (Mich ) and University of Michigan

Evaluates, through pilot-plant and full-scale studies, the efficacy of ozone as a preoxidant for control of TOX, TOC, THM formation potential, and actual THM development Evaluates ozone's ability to promote microflocculation and turbidity removal under varying water quality conditions Completed in 1989 *Published in Journal AWWA*, 81(6):85–92, June 1989.

## Electrochemically Generated Mixed Oxidant Disinfection of Drinking Water Pathogens and Development of *CT* Values [#2558]

University of North Carolina at Chapel Hill

Will evaluate the rate and extent of inactivation of several pathogens and surrogates of pathogens using electrochemically generated gaseous and liquid mixed oxidants. Will estimate *CT* values for these microbes in demand-free water, laboratory waters with added turbidity and NOM, and laboratory waters with added sewage. *To be completed in 2001*.

### Factors Affecting DBP Formation During Chloramination [#803]

University of Houston, University of Texas at Austin, and Metropolitan Water District of Southern California (Los Angeles)

Identifies water chemistry and mixing conditions that promote the formation of DBPs during chloramination to provide insight into the expected behavior of full-scale plants based on pilot testing. Addresses DBP formation in water sources from a wide variety of geographic locations, and develops analytical techniques for identifying currently unknown DBPs. Research partner. USEPA. Published in 1998. (Order 90728)

## Formation and Control of Brominated Ozone By-products [#830]

University of Colorado and University of Illinois at Urbana-Champaign

Studies the impacts of water quality and treatment variables on the formation of brominated inorganic and organic disinfection by-products (DBPs) by ozone and hydrogen peroxide with ozone. Develops an analytical technique for determining total organic bromide. Also performs pilot-scale testing to define DBP profiles across a process train. Published in 1997. (Order 90714)

#### Full-Scale Implementation of UV Groundwater Disinfection Systems [#474]

University of New Hampshire

Will aid utilities in implementing ultraviolet (UV) technology by providing full-scale data on costs, operations, and maintenance experiences Research partner EPRI CEC *To be completed in 1999*.

#### Full-Scale Ozone Contactor Study [#630]

CH2M Hill, East Bay Municipal Utility District (Oakland, Calif), Hackensack (N J) Water Company, and the Suburban Paris Water Authority (France)

Based on extensive evaluation of five full-scale contactors (four types), presents a model to predict contactor performance Provides an approach for utilities to set operating rules for efficient operation while meeting *CT* requirements Published in 1995 (*Order* 90668)

## Impact of Ozone on the Removal of Particles, TOC, and THM Precursors [#228]

University of North Carolina at Chapel Hill

Evaluates the performance of several full-scale plants using preozonation to limit THM formation. Also assesses the use of ozone as a coagulant and filter aid by determining ozone's effect on removal of particulates, TOC, and THM precursors by coagulation, sedimentation, and filtration. Published in 1989. (Out of print)

## Impacts of Ozonation on the Formation of Chlorination and Chloramination By-products [#709]

University of North Carolina at Chapel Hill

Will evaluate the formation of halogenated and non-halogenated disinfection by-products (DBPs) resulting from (1) ozonation followed by chlorination/chloramination, (2) ozonation followed by coagulation and chlorination/chloramination, and (3) ozonation of prechlorinated/prechloraminated water Will use laboratory-scale studies to develop kinetic models for the formation of DBPs from these various approaches Will also verify models at several utilities using pilot- and full-scale ozonation and chlorination/chloramination *To be published in 1999*.

#### Improvement of the Ozonation Process Through the Use of Static Mixers [#2537]

Metcalf and Eddy

Will demonstrate that the use of static mixers can significantly improve the ozonation process in terms of both increased ozone transfer efficiency and enhanced chemical reactions when compared to traditional bubble contactors. Research partner: Compagnie Générale des Eaux. *To be completed in 2001*.

## Improving Clearwell Design for *CT* Compliance [#271]

John Carollo Engineers and University of Illinois at Urbana–Champaign

Evaluates (1) various design configurations to retrofit or design clearwells with baffle systems and/or (2) modification of flow configurations that maximize retention time to meet *CT* disinfection requirements. Research partner: USEPA. To be published in late 1998. (*Order* 90756)

## Inactivation Efficiencies of Emerging Waterborne Pathogens by Chemical Disinfection Processes [#442]

Montgomery Watson, University of Arizona, and Drexel University

Will determine the inactivation efficiencies of conventional and newly developing chemical disinfection processes for emerging waterborne pathogens. Research partner: USEPA. *To be completed in 2000.* 

## Inactivation of *Giardia* Cysts With Chlorine at 0.5°C to 5°C [#107]

Colorado State University

Delineates amount of chlorine and contact time required to inactivate *Giardia* cysts at different disinfectant concentrations and pH ranges in low-temperature waters. These inactivation rates (CT values) were used to develop U.S. surface water treatment performance requirements. Published in 1987. (Out of print)

#### In-Line Ozone and Hydrogen Peroxide Treatment for Removal of Organic Chemicals [#637]

Ridgewood (N.J.) Water Dept., Hackensack (N.J.) Water Company, Spring Valley (N.Y.) Water Company, and Malcolm Pirnie, Inc.

Evaluates both the process performance and the engineering design of an in-line ozone and hydrogen peroxide system. Describes design and scale-up procedures for full-scale facilities. In addition, estimates capital and operating costs and compares them to other types of processes. Published in 1992. (Out of print)

## Integrated Disinfection Design Framework [#295]

CH2M Hill

Presents a new strategy for predicting disinfection effectiveness. Combines contactor hydraulics, disinfectant decay, and disinfectant kinetics into a model that can provide site-specific *CT* values. Published in 1998. (*Order* 90739)

#### Mechanism of Inactivation of Microorganisms by Combined Chlorine [#61]

The Johns Hopkins University

Describes the mechanisms of inactivation of combined chlorine on bacteria, showing that chloramines and chlorine react differently with nucleic components of RNA and DNA and that some chloramine reactions with these components may be reversible. Published in 1987. (Out of print)

## Methodologies for the Determination of Disinfection Effectiveness [#439]

Drexel University and University of Alberta

Will update the AWWARF report Experimental Methodologies for the Determination of Disinfection Effectiveness to include Cryptosporidium and recent information on the experimental methodologies for disinfection of Giardia muris, E. coli, and MS2 virus. To be completed in 1999.

## Minimizing Chlorate Ion Formation in Drinking Water When Hypochlorite Ion is the Chlorinating Agent [#833]

Novatek, Inc., Miami (Ohio) University, American Water Works Service Company, Metropolitan Water District of Southern California (Los Angeles), East Bay Municipal Utility District (Oakland, Calif.)

Evaluates the extent of chlorate ion formation in drinking water when hypochlorite ion is the chlorinating agent. Includes a diskette that contains an easy-to-use predictive model in spreadsheet form to predict chlorate ion formation and hypochlorite ion decomposition in bleach feedstock solutions over time. Provides practical recommendations to mitigate hypochlorite ion decomposition and chlorate ion formation. Published in 1995. (*Order 90675*)

### Modeling Dissolved Ozone in Contactors [#632]

University of North Carolina at Chapel Hill and Los Angeles (Calif ) Dept of Water and Power

Will develop a mathematical model describing ozone transfer, ozone reactivity, and dissolved ozone profiles in different types of contactors. Will verify the model at pilot and full scale and demonstrate its ability to evaluate disinfection efficiency using the CT concept. To be completed in 1998.

## Molecular Mechanisms of *Cryptosporidium* and *Giardia* Inactivation Using Sequential Chemical Disinfection [#492]

Tufts University

Will evaluate the molecular mechanisms of protozoan inactivation by sequential chemical disinfection. Will also determine the molecular basis for synergistic inactivation and the targets of action through various sequential combinations of disinfectant challenges. *To be completed in 2001.* 

## Optimization of Treatment to Mitigate Impacts of Algae and Algae Control on Finished Water Quality [#360]

North Carolina State University

Will develop guidelines to optimize the removal of algae and their extracellular organic matter using conventional water treatment processes. Will identify analytical measurement and testing procedures to predict and monitor the impact of algae on water treatment processes and finished water quality. To be completed in 2000.

#### Optimizing Ozonation for Turbidity and Organics (TOC) Removal by Coagulation and Filtration [#934]

The Johns Hopkins University

Determines the mechanisms of microflocculation and the conditions under which it occurs. Includes a model that allows prediction of whether a given water will be susceptible to microflocculation. Published in 1996 (Order 90703)

## Ozone and Biological Treatment for DBP Control and Biological Stability [#504]

CH2M Hill, East Bay Municipal Utility District (Oakland, Calif), and Tampa (Fla) Water Dept

Evaluates the use of ozone with biological treatment to control disinfection by-products. Also examines the impact of this treatment scheme on biological regrowth and on the maintenance of a disinfectant residual in the distribution system. Provides useful information to utilities that are designing or retrofitting ozone into their plants Published in 1994 (Out of print)

## Ozone and Ozone-Peroxide Disinfection of *Giardia* and Viruses [#503]

University of Alberta

Evaluates disinfection performance criteria for disinfecting *Guardia* and viruses with ozone and ozone plus hydrogen peroxide for waters of various qualities and temperatures. Presents a disinfection protocol for calculating *CT* (concentration ×time) values that would account for advanced oxidation processes based on ozone. Published in 1992. (*Out of print*)

## Ozone Disinfection of *Giardia* and *Cryptosporidium* [#731]

University of Alberta

Evaluates the relative resistance of *Guardia lamblia* cysts, *Guardia lamblia*, and *Cryptosporidium parvum* oocysts to inactivation by ozone in water at cold temperatures Published in 1994 (*Out of print*)

#### Ozone Energy Optimization, Phase III [#475]

Process Applications, Inc.

Will provide feedback to the design community from lessons learned during the ozone plant evaluations conducted during Phases I and II of the project (projects #167 and #284, respectively) Will also include two additional tasks for optimizing on-line ozone residual measurements and predesign considerations for ozone demand and decay Research partner EPRI CEC *To be completed in 1999*.

## Ozone Facility Optimization Research Results and Case Studies [#284]

Process Applications, Inc.

Identifies occurring and recurring factors that limit a facility from achieving optimized ozone system operation. Expands the database for project #167 by conducting additional ozone system evaluations at plants across North America. Documents the results of the evaluations, including the results of the ozone facility technical assistance efforts from Phase I (project #167), which focused on the implementation of optimization strategies. Research partner. EPRI CEC Published in 1998. (Order C0003, available only to AWWARF subscribers.) Nonsubscribers, including AWWA members, can order from EPRIAMP Customer Assistance Center at 800-432-0267.

## Ozone in Water Treatment: Application and Engineering [#421]

AWWA Research Foundation and Compagnie Générale des Eaux

Describes current applications of ozone technology in drinking water treatment in terms of purpose (such as disinfection by-product control, taste and odor control, etc.), design, installation, and operation. Includes case studies and economic considerations. Published in 1991. *Subscribers can order directly from the Research Foundation*. Nonsubscribers, including AWWA members, can order from Lewis Publishers, Inc., by telephoning 800-272-7737 for catalog no. L474LAFD.

#### Ozone System Energy Optimization Handbook [#167]

Process Applications, Inc.

Provides an energy efficiency protocol for ozone systems used in drinking water plants. Documents a series of one-week plant audits focused on the ozone system. Quantifies the improvements that were implemented. Research partner: EPRI CEC. Published in 1996. (Order C0001, available only to AWWARF subscribers.) Nonsubscribers, including AWWA members, can order from EPRIAMP Customer Assistance Center at 800-432-0267.

## Pilot-Scale Evaluation of Ozone and PEROXONE [#402]

Metropolitan Water District of Southern California (Los Angeles), University of California at Los Angeles, and James M. Montgomery Consulting Engineers

Investigates, by means of laboratory, pilot-plant, and field-scale testing, applications of the PEROXONE advanced oxidation process (ozone combined with hydrogen peroxide) for controlling disinfection by-products. Analyzes capital and operational costs of the process. Published in 1991. (Out of print)

#### Removal of Cyanobacterial Toxins From Drinking Water Using Ozone and Granular Activated Carbon [#446]

Australian Water Quality Research Center

Will assess the conditions of ozone residual and contact time under which three algal toxins (microcystin, antoxin-a, and the PSP class of toxins) are destroyed. Will develop, assess, and apply a new technique to detect the formation of toxic by-products. Research partner: United Water International, Pty. Ltd. *To be completed in 2000*.

## Sequential Disinfection Design Criteria for the Inactivation of *Cryptosporidium* Oocysts in Drinking Water [#348]

University of Alberta

Building on work begun in project #273, will develop sufficient data on the inactivation of *Cryptosporidium* for estimation of the parameters for a kinetic model describing the synergistic effects of chemical disinfectants. Will also explore the effect of pH and temperature on the kinetic models. Research partner: USEPA. *To be completed in 1999*.

## Sources, Occurrence, and Control of Chlorine Dioxide By-Product Residuals in Drinking Water [#611]

Virginia Polytechnic Institute and State University and Gilbert Gordon

Determines whether chlorine dioxide, chlorite, and chlorate residuals can be effectively controlled. Focuses on chlorine dioxide generator optimization and chlorite reduction technologies, including GAC and PAC. Also estimates costs of the residual control technologies. Published in 1994. (*Order* 90656)

#### A Study of the Reaction of Ozone and Hydroxyl Radicals With Amino Acids [#832]

University of North Carolina at Chapel Hill

Examines the reactions of molecular ozone and ozone generated hydroxyl radicals with common amino acid species. Uses recently developed analytical methods to evaluate both the organic and inorganic by-products from these reactions, and postulates mechanisms for their reactions. Published in 1995. (Out of print)

## Synergistic Effects of Multiple Disinfectants [#273]

University of Alberta

Will determine the presence of, and quantify the significance of, synergistic effects through the use of multiple disinfectant strategies. Will study the effects of sequential and simultaneous applications of chlorine, chlorine dioxide, monochloramine, UV, permanganate, and ozone on model organisms (*Giardia*, *Cryptosporidium*, and a bacterial system). Research partner: USEPA. *To be completed in 1998*.

## Synergistic Inactivation of *Cryptosporidium* in Natural Waters [#2504]

University of Alberta and Drexel University

Will assess and confirm potential synergistic effects of sequential disinfection of *Cryptosporidium* in natural waters using a well-defined protocol. Will provide data to support *CT* requirements in the Enhanced Surface Water Treatment Rule. Research partner: USEPA. *To be completed in 2001.* 

#### UV-Chlorination for THM Control [#328]

Drexel University and Philadelphia Suburban Water Company (Bryn Mawr, Pa.)

Investigates the feasibility of combining ultraviolet radiation and chlorination to achieve disinfection with minimal THM production, based on a laboratory and pilot comparison of the UV–chlorination process with conventional chlorination. Results indicate that this combined process does not significantly reduce THM production. The project was completed in 1990. (Out of print)

## UV Inactivation of Viruses in Natural Waters [#180]

University of New Hampshire

Will determine the UV dosages needed to kill the human pathogenic viruses (polio, rotavirus, and hepatitis A) as well as the surrogate MS-2 virus in actual groundwater samples. Post disinfection studies will provide side by side comparison of chlorine to chloramines for cross connection protection and regrowth control in distribution systems. *To be completed in 1998.* 

## Physical and Biological Processes for Microbial, Organic, and Disinfection By-product Control

## Adsorption and Filtration Studies Using Iron-Oxide-Coated Olivine as a Medium [#921]

University of Washington

Evaluates an approach to remove both soluble and particulate natural organic matter from water supplies, using olivine grains coated with a thin layer of iron oxide. Includes studies at both laboratory and pilot scale. Published in 1996. (Out of print)

## Adsorption of Pesticides by Powdered Activated Carbon [#715]

University of Illinois at Urbana–Champaign and Kansas City (Mo.) Water and Pollution Control Dept.

Investigates the adsorption of regulated pesticides by PAC. Develops isotherms to predict the removal of pesticides in various concentrations found in drinking water source waters. Also develops methods to account for site-specific characteristics such as temperature, pH, and competition from natural organic matter. Provides a protocol that can be used by utility personnel to predict the site-specific performance of PAC for pesticide removal. Published in 1994. (Out of print)

## Biologically Enhanced Slow Sand Filtration for Removal of Natural Organic Matter [#409]

University of New Hampshire

Investigates and helps define the potential for biologically enhanced slow-rate filtration for removal of organic matter, including the use of ozone in combination with slow-rate filtration. Published in 1993. (Out of print)

## Cascade Air Stripping System for Removal of Semi-Volatile Organic Contaminants: Feasibility Study [#327]

Drexel University

Determines, by means of pilot-plant testing, the practical viability of a counter current packed tower cascade air stripping system that preliminary modeling indicates may be economically and technically feasible for removing semi-volatile organic chemicals. Also refines and validates the mathematical model and develops procedures for the design and scale-up of the cascade system. Published in 1990. (Out of print)

## Colonization of Biologically Active Filter Media With Pathogens [#263]

Montana State University and Metropolitan Water District of Southern California (Los Angeles)

Will establish whether opportunistic and frank pathogenic bacteria can colonize and persist on biologically active filter media. Will also investigate *Giardia* and *Cryptosporidium* for their ability to persist in biological filters. Will determine if these filters are an important source of pathogens entering the distribution system. *To be completed in 1999*.

## Consistent SOC Removal by GAC Adsorption Under Dynamic Conditions [#407]

New York State Dept. of Health and Michigan Technological University

Will determine effects of various operational practices on removal of synthetic organic chemicals by granular activated carbon in order to minimize adverse effects of variable raw water quality and backwashing. To be completed in 1998.

## Control of Organic Compounds With Powdered Activated Carbon [#304]

University of Illinois at Urbana–Champaign and Lyonnaise des Eaux

Determines optimal cost-effectiveness of PAC for trace organics control by identifying (1) water quality problems for which PAC is best suited and (2) promising PAC applications. Also analyzes current applications, determines effects of coagulants and polyelectrolytes on adsorption kinetics and equilibrium capacity of PAC, investigates efficiency of PAC adsorption of SOCs and TOC in a laboratory floc blanket reactor, and reports on field testing of the reactor. Published in 1991. (Out of print)

#### Design of Biological Processes for Organics Control [#712]

University of Alberta

Evaluates whether biofilm process fundamentals and kinetics largely developed for wastewater treatment can be applied to the design and operation of biofilm processes for drinking water treatment. Optimizes the filtration performance of biologically active filters. Also evaluates possible negative impacts of biological treatment on effluent quality and assesses the impact of biological processes on taste and odor reduction. Published in 1998. (*Order* 90722)

#### Development and Testing of Integrated Adsorbent/Membrane Systems for Drinking Water Treatment [#2557]

University of Washington

Will investigate the interactions that control the performance of combined adsorption/membrane filtration systems. Will evaluate the effects of membrane pre-loading with adsorbent on NOM removal, particle removal, and membrane fouling. Will compare the performance and cost of a novel adsorbent/membrane process that uses regenerable adsorbent particles. To be completed in 2001.

#### Effects of Activated Carbon Surface Chemistry and Pore Structure on the Adsorption of Methyl Tertiary-Butyl Ether and Atrazine From Natural Waters [#2556]

North Carolina State University

Will develop a fundamental understanding of the effects of activated carbon surface chemistry and pore structure on the adsorption of organic micropollutants in the presence of natural organic matter. Will elucidate mechanisms by which NOM reduces adsorption of micropollutants onto activated carbon. Will also determine activated carbon characteristics that minimize the adverse impacts of NOM on micropollutant adsorption. *To be completed in 2001*.

### Enhancing Coagulation With Calcium Addition [#389]

The Johns Hopkins University and O'Brien & Gere Engineers, Inc.

Will study the interactions between natural organic matter, calcium, particles, and coagulants to enhance the removal of total organic carbon and minimize the production of sludge. Will determine the mechanisms of calcium enhanced adsorption of NOM onto particles, and the effect of calcium addition on TOC removal and coagulant demand. Will also examine coagulant schemes to enhance removal of Ca-NOM complexes prior to filtration. *To be completed in 1999*.

## Evaluation of Membrane Technologies for Removal of Atrazine and Other SOCs [#412]

Carollo Engineers

Will evaluate the use of low-pressure membrane filtration in conjunction with powdered activated carbon as a polishing treatment in softening water treatment plants. Will optimize nanofiltration as a polishing treatment for the reduction of disinfection by-product precursors, pesticides and herbicides, hardness, and microbial pathogens. Research partners: the Missouri River Public Water Supplies Association, EPRI CEC, and Union Electric. To be completed in 2000.

#### **GAC Filter Adsorbers [#109]**

University of Illinois at Urbana–Champaign and American Water Works Service Company

Describes pros and cons of using GAC in conventional media beds for removing organics and turbidity, based on an evaluation of existing published data, a survey of utilities with retrofitted filter adsorbers, and data collection. Published in 1987. (Order 90524)

#### Humic Substance Removal and Minimizing Trihalomethanes by Ferric Chloride Coagulation [#531]

Georgia Institute of Technology

Investigates the removal of dissolved organic material by ferric chloride coagulation. Establishes iron coagulation diagrams for DOC removal based on pH and coagulant dosages. Also investigates the usefulness of fast atom bombardment mass spectrometry to characterize the DOC. Published in 1995. (Out of print)

## Innovative Biological Treatment Processes in Conjunction With Membrane Filtration for Advanced Water Treatment [#2570]

To be determined

Will explore the potential of integrating several innovative biological and filtration processes for advanced treatment of surface water. Will target processes such as slow sand filtration followed by membrane filtration, slow sand/catalytic conditioner/nanofiltration, and rapid sand filtration operated in a biological mode followed by membrane filtration. Research partner: Tucson Water Department. To be completed in 2001.

## Innovative Electrotechnologies for *Cryptosporidium* Inactivation [#282]

Clancy Environmental Consultants, Malcolm Pirnie, Inc., and University of Arizona

Will explore the potential of several innovative electrotechnologies for the inactivation of *Cryptosporidium* by means of a third party evaluation process. Will conduct four challenge demonstrations of innovative electrotechnologies. Will document power requirements and design considerations for the application of the technology in a range of sizes of water utility operations. Will include cyst seeding studies and inactivation determined by animal infectivity. Research partner: EPRI CEC. Published in 1998. (*Available only to AWWARF subscribers*.) Nonsubscribers, including AWWA members, can order from EPRIAMP Customer Assistance Center at 800-432-0267.

#### Integrated, Multi-Objective Membrane Systems for Control of Microbials and DBP Precursors [#264]

Kiwa N.V., University of Central Florida, Boyle Engineering Corporation, and American Water Works Service Company

Will optimize sequences of different membrane types—microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO)—that can function as a synergistic system for removing microbiological contaminants and DBP precursors. Will address the following important issues: use of staged membranes for pretreatment, minimization of chemical

pretreatment, multiple treatment objectives, process sustainability, fouling minimization, reliability, and operational considerations. Will include development of a protocol for multiple membrane applications for surface water sources. Research partner: USEPA. *To be completed in 2000*.

#### Investigation of Reverse Osmosis and Nanofiltration Processes for Removing Organic Contaminants and the Development of Piloting Procedures for Drinking Water Treatment [#170]

University of Central Florida

Will investigate and model pesticide and disinfection by-product (DBP) precursor removal by diffusion controlled membrane processes. Will also develop a membrane protocol as required by the Information Collection Rule (ICR). Research partner: Kiwa N.V. *To be completed in 1999.* 

#### Microbial Activity on Filter-Adsorbers [#408]

University of North Carolina at Chapel Hill

Quantifies the magnitude and prevalence of water quality changes mediated by microorganisms associated with GAC filter-adsorbers in order to improve overall treatment plant performance by promoting or discouraging microbial–GAC interactions that affect finished water quality. Published in 1992. (*Out of print*)

#### Modifications to the Slow Sand Filtration Process for Improved Removals of Trihalomethane Precursors [#208]

University of New Hampshire

Establishes, by pilot-plant testing of media characteristics and pretreatment schemes and full-scale sampling, the optimal capabilities of slow sand filtration to remove THM precursors in small systems. Also characterizes removed organic matter and microbial populations, determines the process's cost-effectiveness for varying raw water conditions and design parameters, and compares THM-removal performance of slow sand filtration with that of the rapid-rate process. Published in 1989. (*Order 90548*)

#### Natural Organic Matter (NOM) Rejection by, and Fouling of, Nanofiltration and Ultrafiltration Membranes: Bench-Scale and Pilot-Scale Evaluations [#390]

University of Colorado, University of Illinois, and National Institute of Standards and Technology

Will assess the mechanisms of NOM-membrane surface interactions. Will also define the applicability of bench tests in simulating NOM rejection and fouling at pilot and larger scales. *To be completed in 1999.* 

## NOM Adsorption Onto Iron-Oxide-Coated Sand [#635]

University of Washington

Evaluates a novel approach to remove both soluble and particulate natural organic matter from water supplies, using sand grains coated with a thin layer of iron oxide. Includes studies at both laboratory and pilot scale. Published in 1993. (Order 90632)

#### Occurrence and Removal of Volatile Organic Chemicals From Drinking Water; Activated Carbon in Drinking Water Technology [#34]

AWWA Research Foundation and The Netherlands Waterworks Testing and Research Institute (KIWA)

Describes case histories of occurrence and removal of volatile organic chemicals from drinking water and offers guidance in evaluating activated carbon treatment practices for removing organic chemicals from groundwater. Published in two volumes in 1984. (Out of print)

## Optimization and Economic Evaluation of Granular Activated Carbon for Organic Removal [#203]

Metropolitan Water District of Southern California (Los Angeles) and James M. Montgomery Consulting Engineers

Assesses the optimization of GAC to remove trihalomethane precursors (to attain finished water THM concentration of 1–20  $\mu$ g/L), based on modeling, bench-scale, and pilot-plant experimentation. Evaluates the economics of the process by developing cost estimates for six participating utilities. Published in 1989. (*Order* 90550)

## Optimizing Filtration in Biological Filters [#252]

University of Waterloo, Metropolitan Water District of Southern California (Los Angeles), Georgia Institute of Technology, The Johns Hopkins University, Montana State University, Charlotte Smith & Associates, and Process Applications, Inc.

Will address key issues related to optimization of biological filters for multiple objectives, namely, simultaneous particle or floc removal and biodegradation of organic compounds, on a number of source waters and process designs (direct filtration, post-sedimentation, following ozone, etc.). To be completed in 1998.

## Optimum Backwash of Dual Media Filters and GAC Filter-Adsorbers With Air Scour [#427]

Georgia Institute of Technology

Evaluates optimum conditions for backwashing anthracite and GAC media with air scour. Includes formulas for rates of water flow, loss of media, and design specifications. Published in 1991. (Out of print)

## Prediction of GAC Performance Using Rapid Small-Scale Column Tests [#230]

Michigan Technological University

Refines the minicolumn technique of predicting performance of GAC adsorbers for removing trace organic contaminants. Applies a pilot-scale investigation to study the technique's adequacy as a predictive tool for design. Published in 1989. (Out of print)

#### Proceedings of the Conference on Design and Use of Granular Activated Carbon: Practical Aspects [#312]

Reports on a two-day conference co-sponsored by the AWWA Research Foundation and USEPA that focused on the current state of GAC technology and how this information could be used. Covers topics such as regulatory requirements, design, operation, reactivation, cost, alternatives, field experiences, and how well predictive tools work for design and research needs. Published in 1989. (Out of print)

## Removal of DBP Precursors by GAC Adsorption [#816]

Malcolm Pirnie, Inc., University of Cincinnati, and Cincinnati (Ohio) Water Works

Evaluates the use of GAC for disinfection by-product control at six representative utilities. Addresses optimized performance based on pretreatment (coagulation and ozonation plus biological treatment), empty bed contact time, and blending. Discusses the relationship between natural organic matter characteristics and DBP formation. Also provides optimization guidelines and cost estimates for GAC implementation. Research partner: USEPA. To be published in late 1998. (Order 90744)

## Removal of DBP Precursors by Optimized Coagulation and Precipitative Softening [#814]

University of Kansas and Virginia Polytechnic Institute and State University

Will evaluate the degree of improved DBP precursor removal by full-scale water treatment plants optimized for precursor removal rather than removal of turbidity or hardness. Will assess costs and the degree of increased precursor removal as a function of source water characteristics, season, treatment technique, and optimized treatment strategy. Research partner: USEPA. *To be completed in 1998*.

## Removal of Natural Organic Matter in Biofilters [#631]

The Johns Hopkins University

Investigates the ability of a biofilter to remove natural organic matter (NOM) and assesses the likely benefits of reducing NOM by biodegradation. Also investigates preozonation and NOM biodegradation to determine optimal ozone doses. Evaluates sand as a support medium for the microbiological population. Published in 1995. (Out of print)

### Standardized Protocol for the Evaluation of GAC [#518]

University of Cincinnati, Cincinnati (Ohio) Water Works, and James M. Montgomery Consulting Engineers

Develops a standardized protocol for the evaluation of GAC based on intended use in water treatment. Verifies protocols at three field sites. Published in 1992. (Out of print)

## Static Mixers for Mixing in Water Treatment Processes: Coagulation and Disinfection [#558]

Georgia Institute of Technology

Will modify an existing model of static mixers to model the chemical reactions in both alum coagulation and chlorine disinfection. Will investigate the use of static mixers for coagulation using a variety of coagulants, including alum and polymers. Will also investigate static mixers for their effectiveness in the initial mixing of chlorine to inactivate pathogens and for their performance in series with dual disinfectants (chlorine and chloramine). *To be completed in 2000.* 

#### Testing of Thin-Film Composite Nanofiltration Membranes Fabricated From a New Class of Hydrophobic-Hydrophilic Block Copolymers [#559]

University of North Carolina at Chapel Hill and North Carolina State University

Will determine the frequency with which new membrane materials must be rinsed or cleaned as compared to commercially available membranes. Will test for flux decline, natural organic matter (NOM) rejection, characterization of the extent and type of fouling (NOM versus microbial), and effectiveness of cleaning. To be completed in 2000.

### A Zero-Valent Iron Packed-Bed Treatment Process [#2555]

Arizona State University

Will develop and test use of elemental iron in a packed-bed water treatment process for electrochemically reducing problematic inorganics in groundwater. Will optimize the process for nitrate removal. *To be completed in 2001.* 

#### Particulate and Microbial Removal

## Assessment of Potable Water Membrane Applications and Research Needs [#424]

University of Central Florida

Provides information on potable water membrane plants and recommendations for research projects that are necessary to utilize membrane technology in potable water treatment applications. Published in 1989. (Out of print)

## Bench-Scale Production, Characterization, and Application of Polyaluminum Sulfate [#325]

Pennsylvania State University

Identifies conditions that permit the formation of clear and stable polyaluminum sulfates (PAS) by a technique that could be duplicated at a water treatment plant. Evaluates the nature, stability, and coagulative power of PAS. Published in 1989. (Out of print)

#### Biofouling in Membrane Processes [#904]

Orange County (Calif.) Water District

Will identify and quantify physico-chemical and biological factors influencing bacterial attachment to synthetic membrane polymers. Will delineate biofilm growth kinetics and structure as a function of nutrient level and hydrodynamics and will correlate bacterial affinity coefficients and biofilm growth kinetics with membrane performance. Will also develop a qualitative process model of membrane biofouling. *To be completed in 1999*.

## Characteristics of Initial Effluent Quality and its Implications for the Filter to Waste Procedure [#114]

Montana State University

Evaluates the validity of the filter to waste procedure by plant-scale investigation of initial filter effluent quality and pilot-plant study of filter-ripening mechanisms and backwashing techniques that improve initial effluent quality. Also describes quality of initial filtrate, presents guidelines for minimizing degradation of postbackwash

filtered water quality, and discusses whether a filter to waste period for treatment plants is warranted. Published in 1988. (Out of print)

## Control of Residual Aluminum in Filtered Water [#606]

Syracuse University

Determines, by case studies, the processes and conditions that cause elevated levels of residual aluminum in filtered water. Provides treatment guidance to reduce high aluminum levels in finished water. Published in 1994. (Out of print)

## Critical Review of Existing Data on Physical and Chemical Removal of *Cryptosporidium* in Drinking Water [#437]

Drexel University and University of Alberta

Will critically assess past Cryptosporidium research results and conclusions about current knowledge and state of interpretation of experimental results, and will describe the effectiveness of water treatment processes for removing Cryptosporidium. Will develop a statistical model that would predict treatment performance for removing Cryptosporidium. Research partner: USEPA. To be completed in 1999.

#### Design and Operation Guidelines for Optimization of the High-Rate Filtration Process: Volume I—Plant Survey Results; Volume II—Plant Demonstration Studies [#303]

Iowa State University

Presents guidelines for designing and operating high-rate filtration plants capable of producing high-quality finished water (ntu less than 0.2), based on plant-scale validation of key parameters identified through a survey of existing high-rate plants and pilot-plant research. Also provides guidelines for modifying processes and operations of existing plants to achieve high-quality finished water and estimate attendant costs. Results of survey phase published in 1989. Results of pilot and full scale phase published in 1992. (Out of print)

## Determination of Removal Efficiencies of Emerging Waterborne Pathogens [#441]

University of Wisconsin at Madison and Wisconsin State Laboratory of Hygiene

Will determine the removal efficiencies of emerging waterborne pathogens by conventional and innovative water treatment processes. Research partner: USEPA. *To be completed in 2000.* 

## Dissolved Air Flotation: Laboratory, Pilot Plant, and Field Investigations [#536]

University of Massachusetts and South Central Connecticut Regional Water Authority (New Haven)

Investigates dissolved air flotation (DAF) as an alternative to gravity settling. In the first phase, relates air requirements to source water quality and pretreatment conditions, and compares DAF performance with conventional treatment on a lab and pilot scale. In the second phase, evaluates performance of DAF facilities in North America and Europe, and develops cost data for this process relative to conventional treatment. Results of first phase published in 1992 as Dissolved Air Flotation: Laboratory and Pilot Plant Investigations. Results of second phase published in 1994 as Dissolved Air Flotation: Field Investigations. (Out of print)

## Enhanced and Optimized Coagulation for Removal of Particulates and Microbial Contaminants [#155]

American Water Works Service Company, University of Colorado, University of Washington, and The Johns Hopkins University

Will evaluate the effect of enhanced and optimized coagulation, as defined by the pending D/DBP Rule, on particulate and microbial removal. Will include bench-scale studies on 18 waters corresponding to the USEPA TOC-alkalinity matrix and removal of protozoan cysts and oocysts, viruses, enteric bacteria, spores, and bacteriophage. Will perform larger scale testing using similar parameters and develop operational guidelines for utility application. *To be completed in 1999.* 

### **Evaluation of Roughing Filtration Design** Variables [#636]

University of New Hampshire

Evaluates the efficacy of roughing filtration as a pretreatment for additional clarification of raw water for small communities where simplicity of treatment is important. Uses laboratory-scale filters to determine key design features. Also develops a mathematical model of roughing filtration and verifies it by pilot-scale filtration units. Published in 1994. (Out of print)

#### Evaluation of Ultrafiltration Membrane Pretreatment and Nanofiltration of Surface Waters [#601]

James M. Montgomery Consulting Engineers, East Bay Municipal Utility District (Oakland, Calif.), Contra Costa Water District (Concord, Calif.), Lyonnaise des Eaux-Dumez (France)

Evaluates the impact of pre- and post-treatment on low-pressure membrane processes to determine the effect on operation, removal of DBP precursors, tastes and odors, and corrosion control. Develops cost comparisons and analysis for different membrane process schemes. Published in 1994. (Out of print)

## Filter Maintenance and Operations Guidance Manual [#2511]

Black & Veatch

Will develop maintenance and operations guidance relating to optimization of the filtration process, with an emphasis on developing detailed preventative maintenance programs, backwash methods, and techniques for assessing filter performance. Research partner: USEPA. *To be completed in 2001.* 

## Filter Operation Effects on Pathogen Passage [#490]

University of Waterloo

Will evaluate the effects of operational factors (e.g., headloss, turbidity, plant-flow changes, particle counts, and charge) on the passage of pathogens through filters during filter ripening periods, filter-run turbidity and particle spikes, and filter breakthrough events. In addition, will investigate the impact of sudden changes in source water quality on the breakthrough of pathogens. Research partner: M/DBP Council. *To be completed in 2001*.

## Filtration of *Giardia* Cysts and Other Particles Under Treatment Plant Conditions [#80]

Colorado State University

Delineates conditions that have contributed to or permitted passage of *Giardia* cysts by the rapid-rate filtration process. Evaluates applicability to full-scale operation of the findings of pilot-scale studies of rapid-rate filtration (with special reference to low-turbidity water). Also evaluates startup and operation of a newly constructed slow sand filtration system in a watershed known to contain a persistent source of *Giardia* cysts. Published in 1988. (*Out of print*)

## Full-Scale Evaluation of Declining and Constant Rate Filtration [#202]

Environmental Engineering & Technology, Inc., and City of Durham (N.C.)

Compares effluent quality relative to benefits of constant- and declining-rate filtration control methods by evaluating them under a variety of operating conditions at a full-scale plant with split-flow capability. Published in 1992. (Out of print)

## Giardia and Cryptosporidium in Water Supplies [#430]

American Water Works Service Company and University of Arizona

Evaluates more than 60 surface water treatment filter plants in North America for the occurrence and distribution of *Giardia* and *Cryptosporidium* in raw and treated surface waters to determine the occurrence of these parasites and the efficacy of various treatment practices in their removal. Published in 1991. (*Out of print*)

## **Guidance Manual for Coagulant Change-Over** [#2512]

Pennsylvania State University and The Sear-Brown Group

Will develop a guidance manual addressing management and operational considerations for changing coagulants in water treatment plants. *To be completed in 2001*.

## Improving Membrane Operation by Control of Particle Fouling [#2514]

University of Central Florida

Will identify the impact of particles/colloids on membrane fouling. Will perform bench- and pilot-scale studies to investigate fundamental causes and control of particulate fouling. Will also provide guidance to water utilities to quickly assess the particulate fouling potential of waters. *To be completed in 2001.* 

## Is Disinfection a Function of Initial Microbial Concentration? [#2561]

Drexel University

Will evaluate whether inactivation efficiency depends on initial microbial density. Will conduct inactivation studies in two systems (*Giardia muris* with ozone and *E. coli* with preformed monochloramine) using different initial microorganism concentrations. *To be completed in 2001.* 

## Low Pressure Membrane Filtration for Particle Removal [#506]

Boise (Idaho) Water Corporation

Demonstrates the applicability of ultrafiltration membrane separation to water treatment and provides an integrated technical and economic evaluation of the process. Evaluates the cost, efficiency, limitations, and operation and maintenance requirements of the process under a variety of real-world conditions. Published in 1992. (Out of print)

### Manual of Design for Slow Sand Filtration [#404]

Colorado State University, CH2M Hill, Denver (Colo.) Water Dept., the State of Colorado, Black & Veatch, Dayton & Knight, and RBD Consulting Engineers

Describes engineering, design, and construction practices necessary to achieve desired capacity and reliability of slow sand systems given anticipated source water quality conditions. Emphasizes using locally available building components, construction materials, and contractors. Published in 1991. (Out of print)

## Membrane Filtration for Microbial Removal [#817]

Montgomery Watson

Determines the efficacy of available membrane technologies for removing microorganisms to meet regulatory compliance requirements of the Surface Water Treatment Rule and the forthcoming Ground Water Disinfection Rule. Elucidates the mechanism for microbial removal and presents cost estimates for full-scale treatment. Published in 1996. (Order 90715)

## Microbial Removal and Integrity Monitoring of High-Pressure Membranes Used for Water Treatment [#435]

CH2M Hill and University of Illinois

Will assess removal capabilities and develop a reliable method of determining microbial removal effectiveness and integrity of nanofiltration and reverse osmosis systems. Research partner: U.S. Bureau of Reclamation. *To be completed in 2000.* 

#### Mixing in Coagulation and Flocculation [#316]

AWWA Research Foundation international authors committee

Reports on the theory, design, and practice of mixing in coagulation and flocculation by experts from both the chemical engineering and water treatment fields. Published in 1991. (Out of print)

## National Assessment of Particle Removal by Filtration [#908]

Environmental Engineering & Technology, Inc., American Water Works Service Company, and Erie County (N.Y.) Water Authority

Determines the range of particles in filtered effluent as a benchmark for water utilities to use in evaluating treatment performance. Presents particle count data from a 100-plant sampling program in which on-line particle measurements were collected from a number of treatment plants. Provides utilities with particle count information to which they can compare their individual performance. Printed in 1998. (*Order 90757*)

### Optimization of Filtration for Cyst Removal [#703]

Montgomery Watson and Portland (Ore.) Bureau of Water Works

Investigates *Cryptosporidium* and *Giardia* removal efficiencies in a variety of pilot-scale filtration systems. Studies treatment variables such as coagulant type and dose, physical mixing processes, pH adjustment (ahead of filtration), filter aids, and filter media. Also evaluates operational variables such as filter start-up, filter loading rates, length of run, backwash type, and backwash frequency. Published in 1996. (*Order* 90699)

### Ozone as an Aid to Coagulation and Filtration [#403]

University of Massachusetts, Camp Dresser & McKee, Inc., and South Central Connecticut Regional Water Authority (New Haven)

Provides, through laboratory and field studies, a better understanding of fundamental microflocculation mechanisms. Identifies and studies mechanisms responsible for and water quality characteristics contributing to ozone's ability to improve coagulation and filtration. Published in 1993. (Out of print)

#### Polymeric Inorganic Coagulants [#108]

The Johns Hopkins University

Defines appropriate conditions for application of the relatively new inorganic polymers of iron and aluminum salts (both commercially available preparations and those manufactured on site) and when and how they may be used as coagulants in potable water treatment. Published in 1989. (Out of print)

### Procedures Manual for Polymer Selection in Water Treatment Plants [#209]

University of Delaware

Based on utility use of the protocol published for project #81, the manual has been revised. Includes two new modules on polymer charge density and molecular

weight (intrinsic viscosity) determination, deletes the module on bench-scale filters, and improves the remaining modules. Published in 1989. (Out of print)

#### Procedures Manual for the Selection of Coagulant, Filtration, and Sludge Conditioning Aids in Water Treatment [#81]

University of Delaware

Examines existing and proposed test protocols for evaluating coagulant aids (primarily polymers) and describes a single modular protocol that may be implemented by utilities of all sizes and complexities. The protocol was evaluated in project #209. This manual has been replaced by that for project #209.

## Production and Utilization of Polyaluminum Sulfate [#426]

Pennsylvania State University

Continues the evaluation of polyaluminum sulfate as a coagulant for water treatment. Based on the researchers' bench-scale evaluation, determines the ease or difficulty of preparing and using PAS coagulants on pilot and plant scales. Published in 1994. (*Order* 90586)

#### Reaction of Polyelectrolytes With Other Water Treatment Chemicals and Subsequent Effects on Water Quality and Operational Efficiencies [#2509]

University of South Florida and CSIRO (Australia)

Will identify possible chemical reactions between polyelectrolytes and other treatment chemicals and will evaluate the impacts of these interactions on treatment performance. Will provide utilities with recommendations regarding the use of polyelectrolytes with other treatment chemicals to effectively meet water quality and production goals. *To be completed in 2001.* 

## The Removal and Disinfection Efficiency of Lime Softening Processes for *Giardia* and Viruses [#608]

Black & Veatch

Determines the extent of inactivation/removal credit for *Giardia* cysts and viruses that can be given to utilities that use lime softening to treat surface water or groundwater under the direct influence of surface water. Includes bench-scale studies on softened waters at various pH conditions, with and without chemical disinfectant present. Published in 1994. (*Order 90648*)

#### Residual Aluminum in Filtered Water [#111]

Syracuse University and Onondaga County (Syracuse, N.Y.) Water Authority

Evaluates water quality conditions that cause aluminum to remain in solution through the treatment plant and persist in solution or possibly precipitate in the distribution system. Also discusses chemistry and potential causes of residual aluminum and provides guidance on potential measures to minimize aluminum levels in finished water. Published in 1987. (Out of print)

## Selection and Design of Mixing Processes for Coagulation [#613]

University of Illinois at Urbana-Champaign, Contra Costa Water District (Concord, Calif.), Los Angeles (Calif.) Dept. of Water and Power, and James M. Montgomery Consulting Engineers

Examines the effect of rapid (flash) mixing on the efficiency of downstream processes, i.e., flocculation, sedimentation, and gravity filtration. Also determines fundamental mixing characteristics of different rapid mix technologies and addresses scale-up issues. Provides practical design approaches for both rapid mixing and flocculation. Published in 1994. (Out of print)

## Self-Assessment Guide for Surface Water Treatment Plant Optimization [#274]

Process Applications, Inc.

Assists utilities in conducting self assessments to improve performance of existing surface water treatment plants using conventional and direct filtration unit processes. Addresses optimization for particulate removal and for meeting disinfection requirements. Published in 1997. (Order 90736)

## A Study of Water Treatment Practices for the Removal of *Giardia lamblia* Cysts [#74]

University of Washington

Evaluates the ability of full-scale filtration systems (rapid sand, dual media, and diatomaceous earth) operating under ambient conditions to remove *Giardia* cysts and cyst-size particulates. Provides design and operation guidelines for maximizing cyst removal and verifies findings of previous laboratory and pilot-plant studies on cyst-removal techniques. Published in 1989. (*Out of print*)

## Tracer Studies in Water Treatment Facilities: A Protocol and Case Studies [#166]

Provides a protocol that assists utilities in complying with the Surface Water Treatment Rule. Demonstrates many of the points made in the protocol with case studies of tracer analyses completed at utilities. Published in 1996. (*Order* 90692)

## Treatment Process Selection for Particle Removal [#423]

AWWA Research Foundation and the International Water Supply Association

Describes effectiveness of particle removal processes, water quality evaluation, cost considerations, process testing techniques, process optimization, and new technologies. Also describes field experience with use of piloting data to design and operate full-scale particulate removal processes. Published in 1997. (*Order 90701*)

#### Water Treatment Membrane Processes [#826]

AWWA Research Foundation, Lyonnaise des Eaux-Dumez (France), Thames Water Utilities (U.K.), and Water Research Commission (South Africa)

Provides an introduction to the rapidly growing field of membranes in drinking water. Published in 1996. (*Order 90716*)

## **Inorganic Contaminant Removal** and Control

## Application of Bioreactor Systems to Low-Concentration Perchlorate-Contaminated Water [#2530]

Northwestern University

Will evaluate the efficiency of a biological process to reduce perchlorate concentrations of up to 1,000 micrograms per liter to levels of 4–18 micrograms per liter. Will also evaluate the impact of co-contaminants on process performance, characterize process effluents, and define post treatment requirements. *To be completed in 2001*.

## Application of Bioreactor Systems to Low-Concentration Perchlorate-Contaminated Water [#2577]

Pennsylvania State University

Will evaluate the efficiency of a biological process to reduce perchlorate concentrations of up to 1,000 micrograms per liter to levels of 4–18 micrograms per

liter. Will also evaluate the impact of co-contaminants on process performance, characterize process effluents, and define post treatment requirements. *To be completed in 2001.* 

## Arsenic Removal by Enhanced Coagulation and Membrane Processes [#935]

University of California at Los Angeles

Studies the effects of water quality (pH, NOM, particles, and inorganic solutes) on arsenic removal by enhanced coagulation and membrane processes. Examines the mechanisms of arsenic removal by coagulation and rejection by reverse osmosis and nanofiltration. Published in 1996. (*Order* 90706)

### Arsenic Treatability Options and Residuals Evaluation [#153]

University of Colorado and University of Washington

Will compare conventional and advanced treatment options for arsenic removal including ion exchange, iron-oxide-coated sand, activated alumina, and membrane technologies. Will characterize residuals and examine various disposal options. *To be completed in* 1999.

### Assessment of GAC Adsorption for Radon Removal [#907]

Environmental Engineering & Technology, Inc., and University of New Hampshire

Will report on the design and operational criteria for radon removal from groundwater systems by GAC adsorption. Will address the capacity and empty bed contact time of GAC for radon removal, the radioactive build-up on the GAC affecting disposal and worker safety issues, and overall system design. *To be published in 1999*.

#### A Comparative Study of Nonthermal Technologies for Salinity Removal [#413]

Metropolitan Water District of Southern California (Los Angeles)

Will determine if nonthermal desalination technologies such as carbon aerogel CDI (innovative capacitive deionization) and ultra-low pressure reverse osmosis can be used to cost effectively treat river waters and reclaimed water. Research partners: Southern California Edison and EPRI CEC. *To be completed in* 2000.

#### Critical Assessment of Radon Removal Systems for Drinking Water Supplies [#805]

Kennedy/Jenks Consultants

Evaluates available methods for radon removal from drinking water sources, including the review of techniques, off-gas emissions control, and disposal of waste products produced. Published in 1998. (*Order* 90753)

## Drinking Water Denitrification With Entrapped Microbial Technology [#513]

University of North Carolina at Charlotte

Evaluates and demonstrates an innovative treatment technology for nitrate removal, which shows promise for helping small water systems meet existing and future nitrate drinking water standards. Published in 1994. (Order 90634)

## Investigation of Methods for Perchlorate Destruction in Aqueous Waste Streams [#2536]

Pennsylvania State University

Will evaluate non-biological technologies for destruction of perchlorate to allow waste stream disposal or recycle. *To be completed in 2000*.

## Iron and Manganese Treatment for Small Water Systems [#207]

Brigham Young University

Evaluates iron and manganese treatment methods for small systems, based on a literature search and a survey of small utilities. Provides information to help define specific problems and evaluate limitations and costs of possible solutions. The project was completed in 1991. (Out of print)

## Manganese Treatment by the Addition of Sodium Silicate and Sodium Hypochlorite [#60]

University of Tennessee

Describes a statistically derived model to predict the extent of manganese treatment possible, based on experiments that define the effect of lag time between adding sodium silicate and chlorine and the effect of diluting sodium silicate prior to treatment. Published in 1986. (Out of print)

## Radium Removal Using Preformed Hydrous Manganese Oxides [#431]

University of Iowa

Evaluates a simple, inexpensive, and reliable method of radium removal for existing small water systems. Includes design and operational guidelines. Published in 1992. (*Order 90597*)

## Reactions Between Iron, Dissolved Organic Carbon, and Alternative Oxidants [#633]

Virginia Polytechnic Institute and State University

Evaluates how the concentration of raw water organic carbon affects iron complexation and the ability of oxidants to oxidize the complexed iron. Also investigates the fate of complexed iron during coagulation with alum, and how potassium permanganate, chlorine dioxide, and ozone each impact iron removal with alum coagulation. Studies the use of ferrous iron to eliminate chlorite. Published as two reports in 1993: Chlorite Ion Removal by Ferrous Iron Addition (Order 90627) and Impacts of Dissolved Organic Carbon on Iron Removal (Order 90633)

#### Removal of Perchlorate and Bromate in Conventional Ozone/Granular Activated Carbon Systems [#2535]

University of Illinois and Metropolitan Water District of Southern California (Los Angeles)

Will determine whether conventional ozone/granular activated carbon systems can be modified to remove perchlorate and bromate without sacrificing system performance. *To be completed in 2001*.

## Sequestering Methods of Iron and Manganese Treatment [#229]

University of Tennessee

Evaluates methods to increase effectiveness of sodium silicate and chlorine addition for manganese control and for iron control in the presence of calcium. Compares the sequestering ability of sodium silicates and polyphosphates in terms of the chemical basis for treatment differences and costs. Published in 1989. (Out of print)

## Strategies to Control Bromate and Bromide [#156]

University of Colorado

Provides feasible strategies for bromate control through (1) removing bromide, (2) limiting bromate formation, and (3) removing bromate after formation. Based on bench- and pilot-scale studies, evaluates options that utilities can use to achieve bromate concentrations below a targeted level. To be published in late 1998. (Order 90751)

#### Treatability of Perchlorate-Containing Water by Reverse Osmosis and Nanofiltration [#2531]

University of Colorado National Institute of Standards and Technology, and Metropolitan Water District of Southern California (Los Angeles)

Will determine concentration ranges treatable by reverse osmosis and nanofiltration. Will evaluate effects of water quality parameters on process performance and perchlorate removal. *To be completed in* 2001.

## Treatability of Perchlorate in Groundwater Using Ion Exchange Technology [#2532]

University of Houston

Will develop an optimized ion exchange process to address low concentration perchlorate contamination of groundwater *To be completed in 2001*.

## Use of Various Oxidants for the Control of Iron and Manganese [#306]

Virginia Polytechnic Institute and State University

Develops design and operational guidelines for iron and manganese removal systems, based on an evaluation of the removal efficiency of various strong oxidants (ozone, chlorine dioxide, hydrogen peroxide, potassium permanganate, oxygen, and chlorine). Also examines effects of variations in physical and chemical parameters on oxidative removal and interrelates laboratory and full-scale monitoring studies to better define removal mechanisms in full-scale systems. Published as two reports. Removal of Soluble Manganese From Water by Oxide-Coated Filter Media was published in 1989. Alternative Oxidants for the Removal of Soluble Iron and Manganese was published in 1990. (Out of print)

#### **Taste and Odor Control**

## Advances in Taste and Odor Treatment and Control [#629]

AWWA Research Foundation and Lyonnaise des Eaux

Serves as a companion volume to *Identification and Treatment of Tastes and Odors in Drinking Water* (project #118) Covers topics such as source control, various oxidants, granular activated carbon, biological treatment, event management, and analytical techniques Includes a taste-and-odor wheel poster Published in 1995 (*Order 90610*)

## Distribution Generated Taste and Odor Phenomena [#365]

Metropolitan Water District of Southern California (Los Angeles) University of California at Los Angeles, AGBAR-Barcelona Lyonnaise des Eaux, and Philadelphia Suburban Water Company (Bryn Mawr, Pa)

Will identify tastes and odors originating from pipe systems. Will also investigate customer sensitivity to these compounds, their causes, and strategies for improving the organoleptic water quality. Research partner. UKWIR To be completed in 1999.

## Hollow-Fiber Stripping Analysis (HFSA) for Taste and Odor Quantification [#938]

Clarkson University

Develops a modification of closed-loop stripping analysis in order to significantly improve the detection limits of taste- and odor-causing compounds such as geosmin, 2-methylisoborneol (MIB), and trans,2-cis,6-nonadienal. Also models and optimizes this new extraction system. Published in 1996. (Order 90704)

## Identification and Treatment of Tastes and Odors in Drinking Water [#118]

AWWA Research Foundation and Lyonnaise des Eaux

Reviews advances in the analysis and treatment of tastes and odors in drinking water and relates those advances to historical and current water treatment practices Published in 1987 (Order 90518)

### Powdered Activated Carbon for Geosmin and MIB Control [#909]

Manatee County (Fla ) Public Works Dept University of Cincinnati, and Montgomery Watson

Will optimize the effectiveness of powdered activated carbon (PAC) for the removal of geosmin and 2-methylisoborneol (MIB) Will study correlations of geosmin and MIB removal with physical characteristics of carbon and the effects of coagulants on PAC performance *To be completed in 1999* 

## Practical Taste-and-Odor Methods for Routine Operations: Decision Tree [#467]

Virginia Polytechnic Institute and State University, Philadelphia (Pa ) Water Dept and Philadelphia Suburban Water Company (Bryn Mawr Pa )

Will adapt taste-and-odor methods used in other industries for use in routine water utility operations at the water treatment plant, in the field, or in the quality control lab. Will also develop a scenario-based decision tree for selecting which method to use. *To be completed in 2000* 

## Taste and Odor in Drinking Water Supplies—Phase I & II [#55 and #121]

Drexel University, City of Philadelphia (Pa ), Philadelphia Suburban Water Company (Bryn Mawr Pa ), and Lyonnaise des Eaux

Identifies specific compounds and groups of compounds that produce tastes and odors in drinking water using a new sensory panel flavor profile analysis coupled with GC-MS analysis. Develops correlations between flavor profile analysis and instrument analysis of taste- and odor-producing compounds. Clearly details the practical application of the flavor profile analysis technique using odor reference standards and cross-panel comparisons. Published in 1989. (Out of print)

## Taste and Odor in Drinking Water Supplies—Phase III [#302]

Drexel University

Enhances understanding of taste and odor compounds and treatment techniques for these agents by correlating GC and GC-MS data using statistical techniques to verify identified flavor characteristics. Published in 1996 (Out of print)

## Taste-and-Odor Problems Associated With Chlorine Dioxide [#405]

Virginia Polytechnic Institute and State University James M Montgomery Consulting Engineers, and American Water Works Service Company

Determines causes of and methods to control distribution system taste and odor problems related to chlorine dioxide use Evaluates causes through chemical analysis at sites experiencing the problem and through a survey of utilities that use chlorine dioxide. Also investigates powdered activated carbon as a control method. Published in 1991. (Order 90589)

#### **Water Treatment Residuals**

## Advanced Oxidation Processes for Control of Off-Gas Emissions From VOC Stripping [#419]

City of Pasadena (Calif)

Investigates the feasibility of treating volatile organic chemicals in air stripper emissions using one or more combinations of advanced oxidation processes (AOPs) involving UV, ozone, and/or hydrogen peroxide Includes cost estimates of the optimized process Published in 1989 (Out of print)

### Alum Sludge in the Aquatic Environment [#319]

Tennessee Technological University

Investigates effects of treatment plant sludges on a variety of receiving waters by means of laboratory and field-scale evaluation of the impact of sludge on the aquatic environment and the solubilization kinetics of aluminum hydroxide sludges. Studies four field locations for the impacts of alum sludges on benthic macroinvertebrate communities. Published in 1991 (Out of print)

## An Assessment of Cropland Application of Water Treatment Residuals [#717]

Virginia Polytechnic Institute and State University

Assesses the impacts of alum sludge application on groundwater quality, soil moisture retention properties, heavy metals, nutrient mobility in the soil, fertilization requirements, crop yield, and crop quality. Also recommends sludge application quantity, methods, and crop rotation programs for land application of alum sludges as a disposal alternative. Published in 1995 (Out of print)

## Beneficial Reuse of Lime Softening Residuals for Flue Gas Desulfurization [#179]

City of Topeka (Kans)

Advances an alternative method for disposal of softening plant residuals by demonstrating its application at a coal-fired electric generation station as a limestone makeup reagent for flue gas desulfurization Provides data to confirm the merit of reuse as a realistic strategy and addresses attributes for the acceptance and application of the option Published in 1997 (*Order* 90735)

### Coagulant Recovery: A Critical Assessment [#213]

Georgia Institute of Technology and Atlanta (Ga ) Bureau of Water

Reviews operational, water quality, and economic implications of existing coagulant recovery systems in the United States and abroad. Also quantifies economics of sludge recovery versus sludge disposal and discusses methods to increase efficiency. Published in 1991. (Out of print)

### Commercial Applications and Marketing of Water Plant Residuals [#470]

Environmental Engineering & Technology Inc

Will identify the potential beneficial-use options for water treatment plant residuals in commercial, industrial, and environmental applications. Will produce a marketing tool for utilities with guidance on

Beneficial and commercial use of residuals, where to find and how to develop these markets, and recommendations on appropriate waste requirements and handling practices required for end users. To be completed in 1999.

#### Criteria Development for Water Treatment Plant Residual Monofills [#812]

New Jersey Institute of Technology

Presents monofill design and operation criteria for ultimate water treatment plant sludge disposal. Also evaluates sludges from treated waters of various sources and from differing treatment processes to determine their physical and chemical properties. Presents cost comparisons of monofill disposal with other disposal alternatives. Published in 1997. (Order 90707)

#### The Effect of Metals on Thermal Regeneration of Granular Activated Carbon [#530]

University of Illinois at Urbana-Champaign, American Water Works Service Company, and Compagnie Générale des Eaux/PICA

Examines the effect of metals that accumulate on GAC during water treatment and determines their fate during thermal regeneration of GAC. Also elucidates the relationships between the accumulation of metals, the effect on adsorption capacities and profiles, and the multiple thermal regeneration of GAC. Published in 1994. (Out of print)

## An Evaluation of the Technical Feasibility of the Air Stripping Solvent Recovery Process [#83]

Michigan Technological University

Describes specifications and cost considerations for constructing a full-scale air stripping VOC recovery process, based on analysis (using mass transfer models and gas phase adsorption) of data collected from a pilot plant built for use at a municipal water treatment plant. Published in 1987. (Out of print)

### Fundamental Methods for Optimizing Residuals Dewatering [#555]

University of Delaware

Will focus on the type and dose of polymer used in conditioning residuals prior to dewatering and on techniques for monitoring and control of the conditioning and dewatering processes. Will also determine predicted overall savings in polymer and in overall sludge management costs. *To be completed in* 2000.

## Fundamentals and Feasibility of Freeze/Thaw Conditioning of Water Treatment Residuals [#386]

Clarkson University and Gannett Fleming, Inc.

Will determine the influence of three operating parameters on dewaterability: freezing rate, initial solids content, and "curing" time. Will also evaluate the potential cost savings of freeze/thaw dewatering compared to conventional dewatering devices. *To be completed in 1999*.

### Guidance Manual for Disposal of Chlorinated Water [#2513]

East Bay Municipal Utility District (Oakland, Calif.)

Will identify regulatory issues and current practices for disposal of chlorinated water. Will investigate and document the effectiveness of current disposal methods. Will also develop a best practices manual for chlorinated water disposal. *To be completed in 2001*.

### The Hazardous Potential of Activated Carbons Used in Water Treatment [#620]

Environmental Engineering & Technology, Inc.

Reviews the pertinent regulations for the disposal of carbons used in water treatment. Gathers background data from existing plants and includes laboratory analysis to determine the potential hazards of carbon as a waste. Provides utilities with planning, handling, and operation information for GAC facilities. Published in 1994. (Out of print)

#### Ion Toxicity in Membrane Concentrate [#290]

Mickley and Associates, ENSR Consulting & Engineering, and The SeaCrest Group

Will investigate the common ion toxicity characteristics of membrane concentrate and determine whether the toxicity is produced by the membrane or is present in the water source. Will include the Whole Effluent Toxicity test. Will focus on waters from groundwater sources. *To be completed in 1999*.

### Land Application of Water Treatment Plant Sludges [#320]

Pennsylvania State University

Delineates appropriate conditions for land application of treatment plant sludges, taking into consideration physical characteristics of amended soils, available phosphorus, and toxicity of leachates. Published in 1990. (Out of print)

### Landfilling of Water Treatment Plant Coagulant Sludges [#512]

Environmental Engineering & Technology, Inc.

Characterizes water treatment plant sludges to determine the potential of landfill as a disposal method. Examines a variety of water treatment plant sludges and considers sludge-only and codisposal methods of landfilling. Provides a protocol for utilities to use in evaluating their sludge characteristics. Published in 1992. (Out of print)

### Management of Membrane Reject Water to Increase Beneficial Reuse [#498]

Clarkson University

Will characterize membrane reject water and define parameters for possible reclassification or reuse of these waters within state and federal regulatory guidelines. *To be completed in 2001.* 

#### Membrane Concentrate Disposal [#607]

Mickley and Associates

Presents existing chemical characterization and cost data on membrane process waste concentrates from a worldwide literature review. Includes both the characterization and minimization of membrane process concentrates. Also provides a state-by-state regulatory review related to concentrate disposal options. Published in 1993. (Out of print)

### Membrane Treatment of Waste Filter Washwater for Direct Reuse [#2568]

Hazen and Sawyer and Camp Dresser & McKee, Inc.

Will investigate the feasibility of using membrane technology to treat filter backwash water for direct reuse. Research partners: New York City Dept. of Environmental Protection, New York Power Authority, and New York State Energy Research. *To be completed in 2001*.

### Nonmechanical Dewatering of Water Plant Residuals [#905]

Environmental Engineering & Technology, Inc.

Provides applied and practical guidance for the proper design of nonmechanical dewatering systems. Presents design details for components such as underdrains, support media, decanting, conditioning, and pump systems. Incorporates design requirements and sludge characteristics into preplanning techniques to determine the viability for nonmechanical dewatering options. Published in 1998. (*Order 90749*)

#### Recycle Stream Effects on Water Treatment [#514]

Environmental Engineering & Technology, Inc., and American Water Works Service Company

Studies the beneficial and adverse effects of sidestream recycling. Evaluates the impact of recycling practices on coagulation, filtration, and disinfection by-products. Covers a broad range of recycling options in laboratory-and full-scale research. Published in 1993. *Out of print*)

#### Removal and Destruction of Toxic Organic Contaminants in Water Using Adsorption and Photocatalytic Oxidation [#730]

Michigan Technological University

Evaluates adsorption in conjunction with advanced oxidation to remove and destroy organic contaminants. Includes laboratory studies to determine the regeneration efficiency of GAC by ozone activated with ultraviolet irradiation and of GAC and a silica gel adsorbent impregnated with a photocatalyst and subjected to sunlight or a low intensity artificial light. Also describes pilot tests of the most promising techniques on a contaminated groundwater to determine the technical feasibility and estimate cost. The project was completed in 1996, and a summary is available upon request.

#### Scale-Up of an Alum Recovery Process [#473]

Lehigh University

Will demonstrate a two-step alum recovery process in order to develop information about design, recovered alum coagulation performance, and costs for potential full-scale implementation. *To be completed in 2001*.

### Selective Alum Recovery From Water Treatment Residuals [#732]

Lehigh University

Investigates the quality of recovered alum and the long-term durability of a composite membrane containing chelating polymers. Also includes field evaluations of the recovery process and regeneration effectiveness. Presents a process design procedure. Published in 1997. (Order 90719)

#### Slib, Schlamm, Sludge [#212]

AWWA Research Foundation and The Netherlands Waterworks Testing and Research Institute (KIWA)

Examines innovative methods for the treatment and disposal of water treatment plant sludges. Outlines both European and U.S. technologies for beneficial use of sludges. Published in 1990. (Out of print)

## Treatment Options for *Giardia*, *Cryptosporidium*, and Other Contaminants in Recycled Backwash Water [#352]

Environmental Engineering & Technology, Inc., and American Water Works Service Company

Will provide initial sampling of plants to determine the extent to which recycle is a problem. Will provide guidance to utilities seeking design, operational, and modified recycling scenarios to reduce viable cysts and oocysts in recycled backwash water. Will also consider the ramifications of recycling on compliance for disinfection by-products and other contaminants. Will discuss the relative effectiveness of facility modifications or operational changes to remove viable cysts and oocysts and other contaminants from the backwash stream. *To be completed in 1999*.

### Water Treatment Plant Waste Management [#112]

Environmental Engineering & Technology, Inc.

Describes how to determine sludge quantities and characteristics, select a waste management system, assess costs of treatment systems, and optimize system performance. Also describes a pilot procedure and design techniques for nonmechanical dewatering methods. Published in 1987. (Out of print)

#### DISTRIBUTION SYSTEMS

#### Infrastructure

### Assessment of Existing and Developing Water Main Rehabilitation Practices [#314]

Roy F. Weston, Inc., and Massachusetts Water Resources Authority (Boston)

Evaluates available water main rehabilitation techniques in terms of technological and economic advantages and disadvantages. Also demonstrates in a logical sequence how such an evaluation can be performed by local utilities or consulting engineers, showing how input data are to be indexed so that they can be temporally and spatially adjusted. Published in 1990. (Out of print)

### An Assessment of Water Distribution Systems and Associated Research Needs [#706]

Economic and Engineering Services, Inc., Roy F. Weston, Inc., and General Waterworks Corporation

Assesses the condition of selected water distribution systems to identify and prioritize the most critical water distribution system problems facing North American water utilities. Also develops a 10-year research strategy for AWWARF based on identified issues. Published in 1994. (Out of print)

### Criteria for Renovation or Replacement of Water Treatment Facilities [#323]

Environmental Engineering & Technology, Inc.

Provides guidance and methodology needed to assist water utilities in comparing construction of a new plant to the rehabilitation of an existing plant, taking into consideration costs, water quality, versatility, and flexibility. Published in 1991. (Out of print)

#### Decision Support System for Distribution System Piping Replacement and Rehabilitation [#2519]

Roy F. Weston, Inc.

Will develop a decision support system that would facilitate selection of the most appropriate rehabilitation technology or replacement materials. *To be completed in* **2001.** 

#### Demonstration of an Innovative Water Main Rehabilitation Technique: In Situ Epoxy Lining [#808]

WRc inc.

Evaluates an epoxy resin lining process commonly used in the United Kingdom as an alternative rehabilitation technique to Portland cement lining. Demonstrates the lining technique on an existing buried pipeline and evaluates the economics and feasibility of this technique in the United States. Published in 1995; *includes a* 13-minute VHS video. (Out of print)

### Demonstration of Innovative Water Main Rehabilitation/Renewal Techniques [#255]

Roy F. Weston, Inc.

Will describe alternative rehabilitation or replacement techniques to cement-mortar or epoxy resin lining of water distribution pipes. Will identify potentially better and more economical pipe rehabilitation or replacement techniques for the water industry. *To be completed in 1999.* 

#### Develop Decision Criteria to Prioritize Replacement and Rehabilitation of Mains and Appurtenances [#459]

Roy F. Weston, Inc.

Will provide guidance and methodologies for collection of field data and field samples after water main leaks and failures. Based on this information, as well as guidance and methodologies on laboratory analyses, will target, evaluate, and prioritize infrastructure rehabilitation investments. *To be completed in 2001*.

### Development of a Lightweight Composite Trench Cover [#422]

Foster-Miller, Inc.

Investigates alternative materials and material compositions that can replace heavy steel plates currently used to cover road trenches during electric and water line installation and repair. Research partner: EPRI. Completed in 1992. (Out of print) For more information on the cover plate product, TUFCOV, call Don Carmichael at CompositAir, 805-389-4600.

#### Development of Disinfection Guidelines for the Installation or Replacement of Water Mains [#912]

Drexel University

Presents a quantitative basis for determining the adequate contact time and disinfectant concentration to achieve acceptable levels of disinfection following the repair or installation of water mains. Identifies distribution systems that have experienced problems and common features that may be responsible for unsatisfactory disinfection performance. Published in 1998. (Order 90750)

### Distribution System Performance Evaluation [#804]

Roy F. Weston, Inc.

Defines distribution system performance measures, develops measurement procedures and techniques, and establishes national target levels for these measures. Also develops guidelines for utility managers to routinely assess the overall condition of their distribution system in order to identify system and investment needs. Published in 1995. (*Order 90677*)

### Electromagnetic Inspection of Prestressed Concrete Pressure Pipe [#2564]

The Pressure Pipe Inspection Company

Will nondestructively evaluate the integrity of concrete pressure pipe by detecting broken prestressing wires using the remote field eddy current inspection technique. Data collection would assist in determining which pipes need to be repaired or replaced. *To be completed in 2001.* 

## Evaluation of Leak Detection Methods for Pinpointing Leaks in Plastic Water Pipes [#393]

National Research Council Canada

Will evaluate the effectiveness of pinpointing leaks in plastic pipe using acoustic leak detection equipment commonly used by the water industry in North America and promising technologies from other industries. Will emphasize technology and procedures for listening devices and an acoustic noise correlator. Research partner: National Research Council Canada. *To be completed in 1999.* 

#### Evaluation of Polyvinyl Chloride (PVC) Pipe Performance [#708]

Utah State University

Evaluates installation practices, usage, and performance characteristics of PVC pipe used for water distribution. Describes the necessary research and analysis to resolve issues and concerns identified in the evaluation. Published in 1994. (Out of print)

### Main Break Prediction, Prevention, and Control [#461]

Woodward Clyde Consultants and San Jose (Calif.) Water Company

Will identify cause and consequence factors for determining risks from main breaks and leaks. Will develop a methodology for water utilities to determine or assign cumulative risk and time-variable factors to individual pipes, and to assign potential cost and customer service consequences. *To be completed in* **2001**.

#### A Methodology to Determine Residual Life of Cast Iron Water Mains [#280]

National Research Council Canada

Will develop a methodology that will help utilities evaluate the condition of cast and ductile iron water mains by integrating metal loss measurements using nondestructive testing techniques with the strength of deteriorated cast and ductile iron water mains. Will enable a quantitative assessment of water mains undergoing evaluation to determine the deferral of water main replacement. Research partner: National Research Council Canada. *To be completed in 1999*.

#### New Techniques for Precisely Locating Buried Infrastructure [#2524]

Roy F. Weston, Inc.

Will identify and comparatively evaluate methods and emerging technologies for accurately locating metallic and nonmetallic buried assets in a wide range of environments (i.e., in cities, under roads, with different soils). To be completed in 2001.

### Nondestructive Testing of Water Mains for Physical Integrity [#507]

CH2M Hill

Explores the feasibility of using nondestructive testing (NDT) to assess the physical condition of exposed and buried water mains. Describes NDT techniques used in the water, oil and gas industries, and discusses their advantages, limitations, methods of interpretation, and potential use by the water industry. Published in 1992. (Out of print)

### Noninvasive, Nondestructive Assessment of Underground Pipelines [#355]

Texas Research Institute Austin, Inc.

Will evaluate the feasibility of developing technologies that can be used by water utilities to assess the condition of buried pipelines without excavation and coupon sampling. Will select and field screen potential technologies for pipeline condition assessment. *To be completed in 1999*.

### Performance of Prestressed Concrete Pipe [#724]

U.S. Bureau of Reclamation

Studies performance of prestressed concrete pipe widely used to convey water for municipal, industrial, and agricultural use. Examines causes of structural deterioration; effects of pipe design, manufacturing, placement, and protection; and reliable techniques for condition assessment, repair, and rehabilitation of existing pipelines. *AWWARF will not publish a final report*. However, the Bureau of Reclamation has published four related reports, which are available only from NTIS at 1-800-553-6847 or 1-703-487-4650:

- Acoustic Monitoring of Prestressed Concrete Pipe at the Agua Fria River Siphon (December 1994);
   Order PB 95181780; price, \$19.50
- Findings of Petrographic Investigations of Embedded Cylinder Prestressed Concrete Pipe (September 1994); Order PB 95159653; price, \$19.50.
- Historic Performance of Buried Water Pipe Lines (September 1994); Order PB 95146577; price, \$19.50
- Prestressed Concrete Pipe Failure Jordan Aqueduct, Reach 3 (July 1994); Order PB 94214129; price, \$21.50.

#### Pipe Materials Selection Manual [#463]

Texas Research Institute Austin, Inc.

Will review U.S. and international data on application and performance of pipeline materials including liners, joint systems, fittings, and design approaches. Will produce a manual that will include a decision-tree approach to selecting pipe material options. *To be completed in 2000.* 

#### Proceedings: First International Conference on Underground Infrastructure Research [#231]

Identifies research needs, provides information on technologies, addresses common issues, and explores the practicality of utility industry cooperation in maximizing services and system reliability while minimizing operating and capital expenditures. Conference co-sponsors were the AWWA Research Foundation, the American Public Works Association, the American Gas Association, the Canadian Water & Wastewater Association, the Gas Research Institute, USEPA, the Water Pollution Control Federation, and the Water Research Centre. Published in 1989. (Out of print)

### Review of Water Industry Plastic Pipe Practices [#104]

University of California at Berkeley

Compiles and evaluates available information related to migration of organic chemicals through plastic pipe, and to industry plastic pipe practices. Published in 1986. (Out of print)

#### Water Main Evaluation for Rehabilitation/ Replacement [#54]

PEER Systems and City of Philadelphia (Pa.)

Describes modeling methods that provide the prediction measures for estimating and scheduling rehabilitation, replacement, or repair of distribution system components as well as economic factors resulting from breaks. Evaluates water data collection procedures used by six municipal utilities. Published in 1986. (*Order* 90509)

#### Water Utility Experience With Plastic Service Lines [#414]

Brown and Caldwell

Evaluates the extent and possible causes of premature failure of polyethylene and polybutylene water service lines. Updates water industry plastic pipe practices in terms of failure rates for these pipes. Published in 1992. (Out of print)

#### **Corrosion and Materials Deterioration**

### Chemistry of Corrosion Inhibitors in Potable Water [#106]

University of Washington

Examines the formation and nature of scales in the distribution system through an evaluation of different water qualities and corrosion inhibitors. Also evaluates the role of scales in corrosion inhibition and refines corrosion monitoring techniques. Published in 1990. (Out of print)

### Chloramine Effects on Distribution System Materials [#508]

University of North Carolina at Charlotte and HDR Engineering, Inc

Studies the corrosion potential of combined and free chlorines on a wide range of distribution system materials. Includes results of tests on metallic and elastomeric materials commonly found in distribution systems. Published in 1993. (Order 90624)

#### Corrosion and Metal Release for Lead-Containing Plumbing Materials: Influence of NOM and Corrosion Mitigation [#182]

University of Washington

Will study the corrosion of lead-containing materials, focusing on the effects of NOM and corrosion mitigation treatment. Will collect data on the rate of electrochemical corrosion, the rate of lead leaching, and lead speciation. Will also study the morphology of the corroding surfaces and of released colloidal particles. Will analyze the effects of treatment processes using laboratory protocols and exposure of materials in the field. To be published in 1999.

#### Development of a Pipe Loop Protocol for Lead Control [#604]

Economic and Engineering Services, Inc , and Illinois State Water Survey

Using the AWWARF Pipe Loop Model (see project #406), presents a protocol based on field testing the loop at various utility locations. Examines the relationship between time required to reach steady state for metal dissolution and metal concentration. Also determines the correlation of pipe loop results and actual distribution system lead concentrations. Published in 1994. (Out of print)

#### Development of Red Water Control Strategies [#368]

Black & Veatch and Economic and Engineering Services, Inc

Will develop immediate response procedures and long-term solutions to red water problems caused by corrosion of iron pipe. Will also identify practices that can be used to prevent red-water problems from recurring. To be completed in 2000.

#### Economics of Internal Corrosion Control [#311]

Economic and Engineering Services Inc

Assists the water utility manager in determining whether or not to implement a corrosion control program based on a benefit cost analysis of many cost factors. Published in 1989. (Out of print)

### Effects of Electrical Grounding on Pipe Integrity and Shock Hazard [#913]

Boyle Engineering Corporation and M J Schiff & Associates

Evaluates the relationship between electrical currents and the service life of distribution pipe materials Provides guidance to mitigate the potential for electrical shock hazard to utility personnel Recommendations include those relating to shock protection issues, grounding electrical systems to metallic underground water pipelines, and external corrosion caused by current flow Published in 1996 (Order 90702)

### Evaluation of a Pilot Versus Field Distribution Corrosion Monitoring System [#78]

University of Tennessee and Knoxville (Tenn ) Utilities Board

Evaluates the qualitative relationship between results from a laboratory-scale continuous flow corrosion monitor as measured by coupon testing devices and from a full-scale distribution system. Also examines the characteristics of several corrosion inhibitors. Published in 1987. (Out of print)

#### Evaluation of the Effects of Electrical Grounding on Water Quality [#714]

Orlando (Fla ) Utilities Commission and CH2M Hill

Evaluates the water quality degradation due to metal leaching caused by alternating and direct currents. Also studies different grounding scenarios to determine water quality effects. Includes the use of a full-scale model home and verification studies in the field. Published in 1994. (Out of print)

### A General Framework for Corrosion Control Based on Utility Experience [#910]

University of Colorado and HDR Engineering, Inc

Provides guidance that contains case studies and "decision trees" Includes user friendly chemical equilibrium software to analyze the available data, to search for the root causes and solutions to corrosion problems, to develop guidelines for corrosion mitigation that have a high degree of success, to test the validity of the guidelines on the basis of optimization studies performed by large utilities, and to serve as a platform for corrosion control decision-making Published in 1997 as a two-part set A General Framework for Corrosion Control Based on Utility Experience and Control of Pb and Cu Corrosion By-products Using Corrode Software (Order 90712)

### Innovative Techniques for Lead Service Line Location [#813]

Roy F. Weston, Inc.

Presents a comprehensive approach for identifying potential locations of lead service lines. Also includes guidance on how to use an existing utility data base and a service line material identification technique. Evaluates a video fiberscope technique and electrical conductivity methods. Published in 1995. (Out of print)

#### Internal Corrosion of Water Distribution Systems [#62 and #725]

AWWA Research Foundation and the German Union of Gas- and Waterworks (DVGW)

Reports on internal corrosion of potable water system piping material, covering principles of corrosion, corrosion of specific materials, mitigation, assessment, and corrosion control strategies. Second edition published in 1996. (*Order 90508*)

#### Lead Control Strategies [#406]

Economic and Engineering Services, Inc.

Provides guidance to utilities of all sizes on how to approach the lead problem, select treatment alternatives, and determine the effectiveness of a lead control program through monitoring. Includes designing, testing, and developing a pipe loop model for evaluating tap lead levels. Provides detailed plans for the pipe loop. Published in 1990. (Out of print)

### Lead Pipe Rehabilitation and Replacement Techniques [#465]

Economic and Engineering Services, Inc., and WRc inc.

Will test and evaluate existing techniques and promising emerging technologies for lining or replacing lead piping. *To be completed in 2000.* 

## Role of Inorganic Anions, NOM, and Water Treatment Processes in Copper Corrosion [#831]

University of Washington and University of Colorado

Emphasizes the effects of sulfate and natural organic matter on corrosion rates and by-products. Helps to unify existing models of copper corrosion and provides insight into factors controlling the initiation and mitigation of copper corrosion. Published in 1996. (Out of print)

### Role of Phosphate Inhibitors in Mitigating Lead and Copper Corrosion [#387]

University of Colorado and Illinois State Water Survey

Will advance the scientific understanding of when, how, and why phosphate-based corrosion inhibitors work in potable waters. Will answer critical questions of inhibitor solution chemistry on lead and copper solubility using laboratory tests. Will use pipe rig experiments to compare the effects of dosing orthophosphate and polyphosphate on lead and copper by-product release. Will also optimize inhibitor doses in water when beneficial effects of phosphate inhibitors are observed. *To be completed in 1999.* 

#### Maintenance of Water Quality

#### Ammonia Release From Chloramine Decay [#553]

University of Wisconsin at Madison

Will study the influence of ammonia release from chloramine decay on the growth of ammonia oxidizing bacteria. Will evaluate treatment methods for their ability to reduce the frequency of nitrification in distribution systems. Also will develop a model that can simulate the water quality effects associated with chloramine decay and nitrification. *To be completed in 1999*.

### Assessing and Controlling Bacterial Regrowth in Distribution Systems [#309]

American Water Works Service Company, University of California at Irvine, and Montana State University

Provides guidance on assessing the extent and relative importance of biofilm and biological activities on water quality deterioration in distribution systems. Demonstrates which methods and procedures effectively evaluate the potential for biological problems and identifies specific practices to control such problems. Published in 1989. (*Order* 90567)

#### Autonomous Feedback Control of Booster Chlorination Systems for Distribution System Residual Maintenance [#2567]

University of Cincinnati

Will develop an algorithm for identifying locations of chlorine booster units and a feedback control algorithm for optimizing autonomous booster chlorination system operation. Will evaluate algorithms by simulation testing using EPANET. To be completed in 2001.

### Bacterial Regrowth in Distribution Systems [#101]

Montana State University and South Central Connecticut Regional Water Authority (New Haven)

Describes practical tests for bacterial, chemical, and physical parameters that should be performed when modifying treatment processes, based on evaluations using predictive transport processes, bacteriological procedures, and models to monitor effects of treatment practices on water quality, including bacterial populations and regrowth in distribution and storage networks. Published in 1987. (Order 90532)

### Booster Disinfection to Improve Water Quality [#261]

University of Cincinnati and USEPA

Will investigate techniques and develop a manual of best practice for the location and operation of booster disinfection systems. Will aid utilities in compliance with the Total Coliform Rule, D/DBP Rule, and Ground Water Disinfection Rule. *To be completed in 1999*.

#### Case Studies of the Impacts of Treatment Changes on Biostability in Full-Scale Distribution Systems [#361]

Montgomery Watson, American Water Works Service Company, Lyonnaise des Eaux, and University of Central Florida

Will document the changes in biostability and biological quality in full-scale distribution systems following implementation of ozonation or membrane filtration. Will provide information on potential impacts of implementing these treatment methods. Will also include recommendations on how to mitigate negative impacts and enhance beneficial impacts. *To be completed in 1999*.

### Chloramine Decomposition in Distribution System and Model Waters [#937]

University of Iowa

Characterizes the influence of water quality on chloramine decomposition rates. Evaluates and compares chloramine decomposition rates in distribution systems with rates in model systems. Characterizes the nature of the decomposition products and quantifies selected DBPs. Also develops models and fundamental relationships for predicting chloramine decomposition rates. Published in 1998. (Order 90721)

#### Control of Water Quality Deterioration Caused by Corrosion of Cement–Mortar Pipe Linings [#415]

Brown and Caldwell

Examines corrosive effects of various water quality parameters on cement matrices commonly used in cement-mortar pipe linings applied in the field for pipe rehabilitation. Published in 1992. (Out of print)

### Deterioration of Water Quality in Distribution Systems [#77]

Consumers/Pirnie Utilities Service Company

Describes reasons for and extent of water quality deterioration in water distribution systems with different sources and qualities of water. Suggests ways to minimize adverse quality changes, based on examination of corrosion rates and by-products, heavy metals, dissolved gases, and microbiological parameters. Published in 1987. (Out of print)

#### Distribution System Water Quality Changes Following Implementation of Corrosion-Control Strategies [#157]

Economic and Engineering Services, Inc., and Black & Veatch

Will evaluate the impact of plant-scale implementation of corrosion control for lead and copper on water quality in the distribution system (e.g., "red water," turbidity, biological growth). Will monitor distribution systems with a variety of characteristics (such as size, geographic location, population served, water quality, etc.) for water quality changes during the full-scale implementation of new corrosion control strategies. *To be completed in 1999*.

### The Effect of Lower Turbidity on Distribution System Water Quality [#516]

University of Missouri at Columbia

Studies the effects on distribution system water quality of lower effluent turbidity levels. Also discusses the relative costs of treatment changes and the benefits noted from reduced distribution system maintenance. Published in 1993. (Out of print)

### Factors Affecting Microbial Growth in the Distribution System [#183]

Montana State University

Will determine the influence of unsteady-state conditions such as changes in assimilable organic carbon, temperature, and disinfection concentration on coliform growth in the distribution system. In pilot plant experiments, will confirm correlations between operational and environmental variables and coliform regrowth events observed in the two-year field survey

conducted as part of project #704 Will also determine the effect of monochloramine on steady-state coliform-containing biofilms in pilot systems *To be completed in 1999.* 

### Factors Limiting Microbial Growth in the Distribution System [#704]

Montana State University, American Water Works Service Company, and South Central Connecticut Regional Water Authority (New Haven)

Describes factors that influence the growth of microorganisms, particularly coliforms, in distribution systems. Determines the effect of physiology and substrate composition on coliform colonization, the influence of temperature, assimilable organic carbon concentration, disinfectant concentration, and pipewall material on microbial colonization, and field conditions that correlate with regrowth events. Validates a pipe line model to predict regrowth events. Published in 1996 as two reports. Factors Limiting Microbial Growth in Distribution Systems. Laboratory and Pilot Scale. Experiments (Order 90708) and Factors Limiting Microbial Growth in Distribution Systems. Full Scale Experiments (Order 90709)

# Formation, Occurrence, Stability, and Dominance of Haloacetic Acids and Trihalomethanes in Treated Drinking Water [#339]

University of North Carolina at Chapel Hill, Metropolitan Water District of Southern California (Los Angeles), Montgomery Watson, and American Water Works Service Company

Will investigate the occurrence of haloacetic acids (HAAs) and trihalomethanes (THMs) in treated drinking water and determine conditions that contribute to the dominance of one group of disinfection by-products over the other in distribution systems. Will conduct bench and field studies in several distribution system water sources to investigate factors that contribute to the formation of THM and HAA. Research partner. M/DBP Council. To be completed in 1999.

#### Guidance Manual for Monitoring Distribution System Water Quality [#2522]

Economic and Engineering Services, Inc. and Black & Veatch

Will provide water utilities with guidance on how to design and implement a distribution system water quality data collection and analysis program. Will include a comprehensive approach for collection and analysis of water quality information to make costly infrastructure improvements, document benefits of operational procedures, and address consumer complaints. To be completed in 2001

### Guidance Manual to Maintain Water Quality Within Distribution Systems [#357]

Economic and Engineering Services Inc., Black & Veatch, and Consumers Water Company

Will identify water quality degradation that can occur during distribution system operation and maintenance Will recommend operational, maintenance, and design practices that can prevent or minimize water quality degradation. Will also determine which water treatment plant operations can be modified to improve distribution system water quality. *To be completed in 1999.* 

#### Guidelines for Evaluating and Controlling Biological Regrowth in the Distribution System [#373]

Carollo Engineers

Will develop guidance for water quality managers on controlling biological regrowth in the distribution system. Will compare and contrast the various methods for assessing regrowth, and will document how utilities have implemented these methods. *To be completed in* 1999.

### Identification and Control of Fungi in Distribution Systems [#269]

International Mycological Institute, WRc plc, and Biosan Laboratories Inc

Will study the correlations of fungi, water source, treatment procedures, and nutrient availability to taste and odor events in treated drinking water. Will investigate treatment and control strategies. Will develop and assess a simple test, based on the presence of indicator organisms, to monitor the presence of problem fungi species and to predict potential taste and odor episodes. *To be completed in 2000*.

### Impact of Wet-Pipe Fire Sprinkler Systems on Drinking Water Quality [#158]

Boyle Engineering Corporation and Poole Fire Protection Engineering

Discusses whether there is a significant health hazard associated with wet-pipe fire sprinkler systems and identifies ways to effectively safeguard the public health if a health hazard exists. Reports on a field testing program with 30 Canadian and U.S. participating utilities. Published in 1998. (Order 90752)

## Impacts of Fire Flows on Distribution System Water Quality, Design, and Operation [#2554]

To be determined

Will determine the economic and water quality impacts of designing water distribution systems to meet fire flows. Will determine if fire flow requirements are appropriate for modern situations and identify possible alternatives. Research partner. Kiwa N. V. To be completed in 2002.

### Implementation and Optimization of Distribution Flushing Programs [#515]

Villanova University

Evaluates and reviews techniques, equipment, and programs to help utilities plan and implement a logical distribution system flushing program. Discusses existing flushing programs and provides practical information to help utilities optimize their flushing programs—or to start a program if they do not have one in place—and thereby improve distribution system water quality. Published in 1992. (Order 90600)

### Influence of Distribution System Infrastructure on Bacterial Regrowth [#2523]

Black & Veatch and Montana State University

Will determine the impact of distribution infrastructure materials on bacterial regrowth. Will provide water systems with recommended actions and viable strategies for control of regrowth, including alterations in infrastructure. To be completed in 2001

## Investigation of Biological Stability of Drinking Water in Treatment Plants and Distribution Systems [#154]

Montana State University, University of Waterloo, and American Water Works Service Company

Will examine how treatment processes affect biological stability in the distribution system. Will also determine how biodegradable organic matter (BOM) and components of BOM influence distribution system regrowth. *To be completed in 1999*.

#### Leachate From Organic Coating Materials Used in Potable Water Distribution Systems [#105]

New York State Dept of Health

Details the effects of chlorination on the leaching rate and the composition of leachate of common coatings of water supply tanks and pipelines. Focuses on laboratory and field tests of existing and new applications of coal tar, asphalt, chlorinated rubber, vinvl, and epoxy. Published in 1989. (Out of print)

### Maintaining and Operating Finished Water Storage Facilities [#254]

Economic and Engineering Services, Inc., Consumers Water Company CH2M Hill and Consumers Applied Technologies

Will develop a guidance manual for the inspection and maintenance of storage tanks and reservoirs to avoid or correct water quality problems. Will elucidate issues such as microbial contamination of the tank, biodegradation of coatings, failure in screens, and avian contamination. Research partner. UKWIR. To be published in 1999.

### Microbial Impact of Biological Filtration [#917]

American Water Works Service Company, Montana State University, Thames Water Utilities (U K ), and École Polytechnique de Montreal

Documents the positive and negative impacts of biological filtration on the microbial quality of drinking water. Examines the changes in microbial populations through conventional and biologically active treatment processes, evaluates the effects of microbial antagonism within biologically active filters, evaluates the release and impact of carbon fines on distribution biofilms, and evaluates the microbial populations in four full-scale treatment systems. Research partner. USEPA. To be published in late 1998. (Order 90743)

### Nitrification Occurrence and Control in Chloraminated Water Systems [#710]

Economic and Engineering Services, Inc

Identifies the extent and causes of nitrification in utilities currently using chloramines as a disinfectant Also identifies waters prone to nitrification problems, and the operational, chemical, and microbiological parameters that lead to an occurrence Determines the impacts of chloramine chemistry, temperature, pH, and detention time on nitrification and develops a protocol to predict a nitrification occurrence Published in 1995. (Order 90669)

### Occurrence and Control of *Mycobacterium* avium Complex [#270]

American Water Works Service Company and Virginia Polytechnic Institute and State University

Will survey a variety of water systems, locations, and treatment systems. Will also determine factors that favor the growth of Mycobacteria in water and examine their resistance to free chlorine, chlorine dioxide, ozone, and chloramine disinfection. *To be completed in 2000.* 

#### Optimizing Chloramine Treatment [#610]

Economic and Engineering Services, Inc.

Provides a chloramination optimization manual for utility use. Reviews the regulatory setting, provides a literature review, presents case studies, and describes the resource requirements of chloramination optimization strategy. Published in 1993. (*Order 90620*)

### Pathogen Intrusion Into the Distribution System [#436]

Economic and Engineering Services, Inc., American Water Works Service Company, and University of Kentucky

Will determine how microbial pathogens enter the distribution system, particularly when treatment appears to be providing adequate multiple-barrier protection, and will estimate the extent of pathogen contamination by different sources of intrusion. Will also evaluate the effectiveness of distribution system maintenance practices in protecting the distribution system from pathogen intrusion. In addition, will provide recommendations for monitoring programs that detect distribution system contamination by pathogens. Research partner: USEPA. *To be completed in 2001*.

### Pathogens in Model Distribution System Biofilms [#936]

Montana State University

Determines the ability of opportunistic and frank pathogens to colonize and persist in mixed population biofilms under conditions relevant to drinking water distribution systems. Published in 1998. (*Order* 90738)

# The Role of Natural Organic Matter in Structuring Microbial Communities— Implications for the Treatment of Drinking Waters and the Control of Biofilms [#2562]

Stroud Water Research Center

Will study structure and composition of natural organic matter and biodegradable organic matter, and structure of heterotrophic bacterial communities supported by raw and treated drinking water. Will also evaluate the responses of microbial communities to seasonal changes in NOM and temperature. *To be completed in 2001*.

#### The Role of Pipe-Water Interface in the Formation of Disinfection By-products and Loss of Disinfectants in Drinking Water [#293]

University of Iowa

Will evaluate the significance and role of model and collected pipe deposits in the formation of selected disinfection by-products in chlorinated and chloraminated water. Will also assess the significance and role of pipe deposits in disinfectant loss. *To be completed in* 1999.

## Travel Times and Water Quality in Deadends of a Municipal Distribution System [#294]

University of Cincinnati and USEPA

Will characterize the patterns of water consumption and water quality in deadend water mains to improve the ability to model and predict water quality problems associated with travel times. *To be completed in 1999*.

#### Water Quality Modeling of Distribution System Storage Facilities [#260]

Walter Grayman Consulting Engineer, University of Michigan, SSESCO, Charlotte Smith & Associates, and Blue Ridge Numerics

Will characterize water quality conditions and changes in water storage reservoirs. Will develop a hydraulic model with a water quality model overlay that can be used to determine the effects of daily "fill and draw" cycles. Will also evaluate optimum design and operation of distribution system tanks and reservoirs. Research partner: UKWIR. To be completed in 1998.

#### **Distribution System Management**

## ☐ Characterization and Modeling of Chlorine Decay in Distribution Systems [#815]

Montgomery Watson

Determines how chlorine decay and trihalomethane formation depend on distribution system characteristics and operating regimes. Also develops field sampling protocols to calibrate and verify computer models that can be used industry wide. Includes an AWWARF version of EPANET, a computer water quality model. Published in 1996. (*Order* 90705)

#### Evaluating Residential Water Meter Performance [#206 and #524]

University of Oklahoma

Evaluates meter headloss and accuracy as they relate to meter wear and meter design, for positive displacement residential water meters Published in 1991. (Out of print)

### Guidance for Distribution System Operation [1#457]

Roy F. Weston, Inc.

Will produce a comprehensive guidance manual for evaluation and operation of a water distribution system for reliability and water quality maintenance. Will include recommendations on topics such as valve maintenance needs, system maintenance needs, system reliability and evaluation, and fire hydrant maintenance schedules. *To be completed in 2000*.

### ☐ Quantifying Future Rehabilitation Needs [#265]

Roy F. Weston, Inc., University of Karlsruhe (Germany), and Philadelphia (Pa.) Water Dept.

Modifies and applies to North American water systems an existing computer model that was developed at the University of Karlsruhe. The model forecasts pipe rehabilitation needs and rates as a function of pipe material, pipe technology, and environmental stress. Completed in 1998. A report with software is available only to AWWARF subscribers.

#### Spatial Demand Allocation for Distribution System Design [#2569]

Los Angeles (Calif.) Dept. of Water and Power and A & N Technical Services, Inc.

Will address problems associated with identification and spatial allocation of water demands used for distribution system planning and design. Research partner: Los Angeles Dept. of Water and Power. *To be completed in 2001*.

#### Water and Revenue Losses: Unaccounted-for Water [#103]

Brigham Young University and Community Consultants Inc.

Provides guidance on standardized terms and on advantages and disadvantages of methods to reduce unaccounted-for water, based on a literature search and compilation of information from more than 100 water audits. Published in 1988. (*Order 90531*)

#### Water Quality Modeling in Distribution Systems: Conference Proceedings [#624]

Reports on a two-day workshop co-sponsored by the AWWA Research Foundation and the USEPA's Drinking Water Research Division. Emphasizes the research, development, and technology transfer needs associated with this fast emerging field. Published in 1991. (Out of print)

#### MONITORING AND ANALYSIS

#### **Methods Development**

### Advancing Cryptosporidium parvum Detection Methodologies [#2502]

U.S. Dept. of Agriculture

Will further advance the application of nucleic acid amplification, cell culture, enzyme-linked immunosorbent, and fluorescent *in situ* hybridization techniques for the detection of *Cryptosporidium parvum*. Research partner: USEPA. *To be completed in 2001*.

### Analytical Chemistry of Arsenic in Drinking Water [#914]

Montgomery Laboratories

Evaluates graphite furnace atomic absorption (AA), hydride generation AA, and hydride generation inductively coupled plasma-mass spectrometry for low level arsenic determination and chemical speciation. Evaluates concentration methods and methods for chemical speciation. Published in 1998. (Order 90729)

### Analytical Methods for Polymers and Their Oxidation By-products [#915]

WRc inc. and University of North Carolina at Chapel Hill

Investigates the effect of oxidants on polyacrylamide, a poly-diallyldimethyl ammonium chloride, and an epichlorohydrin-dimethylamine copolymer, monomers, and polyelectrolyte contaminants. Improves analytical methods for the determination of these polyelectrolytes. To be published in late 1998. (*Order* 90741)

### Application of PCR Technologies for Virus Detection in Groundwater [#916]

American Water Works Service Company

Evaluates the application of polymerase-chain-reaction technology for virus detection in groundwater. Reports the occurrence of enteroviruses, hepatitis A virus, Norwalk virus, and rotavirus in 250 groundwater sources. Research partner: USEPA. Published in 1998. (Order 90740)

### Application of Surrogate Measures to Improve Plant Performance [#363]

Utah State University and CH2M Hill

Will evaluate the use of microbial surrogates for assessing water quality and treatment plant performance. Under full-scale conditions, will study a number of surrogates as operational tools to improve process control and reduce the health risks associated with microbial contaminants. To be completed in 1999.

### Assimilable Organic Carbon Measurement Techniques [#509]

Academy of Natural Sciences of Philadelphia and American Water Works Service Company

Refines and field tests a simplified, routine bioassay technique that permits utilities to easily monitor nutrient fluctuations and adjust treatment processes to minimize bacterial regrowth in distributed and stored waters. Published in 1993. (Out of print)

#### Biological Particle Surrogates for Filtration Performance Evaluation [#181]

Colorado State University

Will determine species of biological particles that mimic the behavior of pathogenic species such as viruses, bacteria, and protozoan cysts in coagulation and filtration. Will also ascertain relationships between removals of test particles and turbidity and particle removals. *To be completed in 1999*.

### Characterization of Natural Organic Matter and Its Relationship to Treatability [#603]

Malcolm Pirnie, Inc., and University of Colorado

Investigates the physical and chemical properties of aquatic natural organic matter and the relationship of these to treatability by coagulation, activated carbon adsorption, disinfection by-product formation, and assimilable organic carbon formation following ozonation. Provides recommendations to utilities on specific raw water parameters to measure in order to predict the impact of NOM on treatability. Published in 1993. (Out of print)

## Characterization of the Polar Fraction of NOM With Respect to DBP Formation [#451]

Metropolitan Water District of Southern California (Los Angeles), University of Colorado, Lyonnaise des Eaux, and University of Poitiers (France)

Will develop methods to isolate and characterize the polar (nonhumic) fraction of natural organic matter (NOM) from different source waters and points of treatment. Will also study the reaction of the polar fraction of NOM with disinfectants to evaluate the type and yield of disinfection by-products produced. *To be completed in 1999*.

### The Colilert System for Total Coliforms and Escherichia coli [#205]

Yale University and South Central Connecticut Regional Water Authority (New Haven)

Evaluates a new medium that simultaneously enumerates coliforms and *E. coli* in drinking water within 24 hours, based on studies conducted by large and small water utility laboratories. The method has been approved by the USEPA. Published in 1991. (*Order 90576*)

### Comparison of the Colilert Method and Standard Fecal Coliform Methods [#425]

Yale University

Compares the coliform monitoring method evaluated in project #205 with standard fecal coliform testing methods to determine practicality for positive identification of bacteria of fecal origin, with direct interpretive applications for assessing potability of drinking water. Published in 1994. (Out of print)

### Cryptosporidium and Giardia Antibody Protocol [#358]

Wisconsin State Laboratory of Hygiene and Indiana University at Kokomo

Will develop a protocol for evaluating various antibodies that can be used for the detection of *Cryptosporidium* and *Giardia* in water samples. Will include methods of correlating specific properties of antibodies and methods of correlating antibody activity between different types of assays. *To be completed in* 1999.

#### Cryptosporidium parvum Viability Assay [#351]

University of Alberta

Will develop a methodology for determining viability and/or infectivity of *C. parvum* in finished drinking water. *To be completed in 1999*.

#### Cryptosporidium Viability Study [#395]

Clancy Environmental Consultants, Thames Water Utilities (U.K.), University of Arizona, and Scottish Parasite Diagnostic Laboratory

Will compare at least three different methods for determining the viability and infectivity of oocysts: DAPI–PI vital stain, mouse infectivity, and other vital dyes. Will use strict quality assurance conditions to ensure meaningful comparisons and will consider oocyst age and effects of treatment stresses. Research partner: UKDWI. *To be completed in 1999*.

### Detection and Occurrence of Caliciviruses in Drinking Water [#345]

Eastern Virginia Medical School Center for Pediatric Research

Will develop a molecular-based assay to detect a broad range of calicivirus strains. Will apply the assay to environmental samples and determine the occurrence of caliciviruses in source, finished, and ground waters. *To be completed in 1999.* 

### Detection of *Cryptosporidium* and *Giardia* by Flow Cytometry [#283]

Wisconsin State Laboratory of Hygiene

Evaluates the use of flow cytometry to improve detection of *Giardia* and *Cryptosporidium* using the immunofluorescence assay. *Published as "Using Flow Cytometry to Detect Protozoa" in Journal AWWA 89(9):104–111, September 1997.* 

#### Development and Evaluation of a Rapid and More Highly Sensitive Methodology for the Detection of Human Viruses in Water [#211]

University of Hawaii and Honolulu (Hawaii) Board of Water Supply

Describes the applicability of an enzyme immunoassay technique and its modifications for the rapid and quantitative detection of epidemiologically significant human enteroviruses in water. Published in 1989. (Out of print)

#### Development and Laboratory Evaluation of the Haloform Potential Tests [#204]

University of Massachusetts at Amherst

Examines validation of various haloform potential tests to fully develop a set of analytical procedures for Haloform Formation Potential and compare to other THMFP surrogates. Published in 1989. (Out of print)

#### Development of Analytical Methodology to Identify Species in Phosphate-Based Corrosion Inhibitors [#911]

Research Triangle Institute

Presents an analytical method for the identification and quantitation of orthophosphate and polyphosphate species in drinking water. Studies method performance with laboratory-prepared samples and with drinking water samples from different geographic regions. Provides a detailed analytical protocol. The project was completed in 1996, and a report is available upon request.

## Development of an Improved, Direct Method for the Determination of Haloacetic Acids [#163]

Midwest Research Institute

Will develop a direct method for the determination of all nine haloacetic acids using a preconcentration technique and ion chromatography. Will compare this method with current USEPA methods. *To be completed in 1998*.

#### Development of a Test to Assess Cryptosporidium parvum Oocysts Viability: Correlation With Infectivity Potential [#609]

University of Arizona

Develops and field tests a method for determining *C. parvum* viability that can be related to infectivity potential. Includes use of vital dyes, differential interference contrast microscopy, and phase contrast microscopy. Published in 1993. (*Out of print*)

### Development of Haloform Potential Tests for Water Treatment Plant Control [#73]

Texas A&M University

Evaluates a new test that utilizes the formation of iodoform or bromoform as an indicator of THM formation potential. Published in 1987. (Out of print)

### Disinfectant Residual Measurement Methods [#102 and #528]

Miami (Ohio) University

Reviews all current disinfectant residual measurement techniques for free chlorine, combined chlorine, ozone, and chlorine dioxide, with special attention to interferences. First published in 1987. Second edition published in 1992. (Out of print)

### Enteric Virus Detection in Water by Nucleic Acid Methods [#612]

University of North Carolina at Chapel Hill

Develops a rapid, sensitive, and specific method for the detection of viruses in drinking water by amplification of viral nucleic acids followed by detection using nonradioactive gene probes. Published in 1997. (*Order* 90711)

#### The Evaluation of Indicator Bacteria by Molecular Fingerprinting at Critical Control Points in the Source Water, Treatment Train, and the Distribution System [#388]

Yale University School of Medicine and South Central Connecticut Regional Water Authority (New Haven)

Will characterize and compare the most important bacterial indicators to determine if they are the same or different at critical control points from the source and through the treatment train and distribution system. Will also study stressed or injured coliform bacteria to determine if there are molecular markers associated with bacteria exposed to chemical and mechanical stressors. *To be completed in 1999.* 

### Evaluation of Surrogate Organic Parameters as an Indicator of Water Quality [#72]

University of Massachusetts at Amherst

Statistically evaluates data bases of information collected from full-scale and pilot-plant research projects that examined treatment systems for organics removal. Sparse data, multiple phases, and large differences between sites and individual GAC's limit the usefulness of these data for the development of surrogate equations. The project was completed in 1989. (Out of print)

#### Evaluation of the By-products Produced by the Treatment of Groundwaters With Ultraviolet Radiation (UV) [#809]

University of New Hampshire

Reports if, and what, by-products are produced by UV disinfection, and if UV influences post-disinfection by-product formation. Published in 1996. (*Out of print*)

#### Fatty Acid Profiling and Its Applicability to the Drinking Water Industry for the Identification of Environmental Bacteria [#534]

Hackensack (N.J.) Water Company

Evaluates a chemistry analytical method for the fatty acid profiling of bacteria isolates to identify, monitor, and understand changes in distribution system bacterial populations caused by water quality, treatment, and environmental factors. Enables reliable identification of microbes that are difficult to classify using conventional biochemical methods. Published in 1995. (*Out of print*)

## Feasibility of Fast Response Testing for Coliform Bacteria in the Distribution System [#2521]

Thames Water Utilities, U.K.

Will determine the feasibility of developing, or transferring, techniques or methods to rapidly assess the presence of coliform bacteria in distribution systems. *To be completed in 2000.* 

## Impact of Sample Collection and Processing on *Cryptosporidium* Viability and Infectivity [#443]

University of South Florida

Will evaluate the effect of various concentration techniques on the viability and infectivity of purified *C. parvum* oocysts. Will demonstrate the feasibility of using a cell culture technique to assess oocyst infectivity. Will also determine a procedure most advantageous for recovery efficiency without compromising oocyst viability and infectivity. *To be completed in 2002*.

#### Improving the Immunofluorescence Assay (IFA) Method for *Giardia* and *Cryptosporidium* [#259]

New York State Dept. of Health-Wadsworth Laboratories and Health Research, Inc.

Will address the limitations of the current ICR method, including filtration, concentration, flotation, and identification to increase recoveries and reproducibility. Will compare modifications to this method with the current method and include limited field testing. *To be completed in 1999*.

## Male-Specific Coliphages as Indicators of Viral Contamination of Drinking Water [#429]

University of North Carolina at Chapel Hill

Assesses the use of coliphages as human enteric viral and fecal indicators of water treatment process effectiveness to ensure removal efficiencies prescribed by regulatory agencies. Published in 1995. (Out of print)

### Measurement of Biodegradable Organic Matter With Biofilm Reactors [#729]

Academy of Natural Sciences of Philadelphia

Validates an immobilized biofilm reactor method capable of measuring BOM concentrations in drinking water in two hours. Also determines the precision, bias, detection limit, and temporal variability of the reactors. Compares reactors to other assays of BOM. Published in 1996. (Out of print)

### Method for *Giardia* and *Cryptosporidium* Detection and Viability [#253]

Thames Water Utilities (U.K.) and Scottish Parasite Diagnostic Laboratory

Will evaluate methods that improve *Giardia* cyst and *Cryptosporidium* oocyst recovery and identification efficiencies and that enable simultaneous viability determination. Will also identify simpler, rapid methods that require less technical expertise than those methods currently available and that are less labor intensive. Research partner: USEPA. *To be completed in* 1999.

## Methods for Assessing the Biological Growth Support Potential of Water Contact Materials [#410]

National Sanitation Foundation

Develops a standardized BGSP testing protocol for evaluating water contact materials such as linings, coatings, gaskets, and sealants. Emphasizes development of a reliable, rapid, and inexpensive protocol that gives consistent results when performed by utilities. Published in 1993. (Out of print)

#### Natural Organic Matter in Drinking Water: Origin, Characterization, and Removal— Workshop Proceedings [#842]

Presents 20 papers from a September 1993 workshop on natural organic matter. Discusses issues of the origin of NOM, the impacts on treatment processes and DBP formation, the available characterization techniques, and techniques for removal. Published in 1994. (Out of print)

### New Approaches for Isolation of *Cryptosporidium* and *Giardia* [#364]

Clancy Environmental Consultants and Thames Water Utilities (U.K)

Will evaluate improved collection, elution, concentration, and purification steps for protozoan analysis. Will present a stepwise protocol, provide information on reproducibility and accuracy, recommend acceptable ranges of variances for the data, and outline the limitations, equipment, and personnel required. *To be completed in 2000*.

#### Non-coli Escherichia Identification [#734]

USEPA, East Bay Municipal Utility District (Oakland Calif), and Wisconsin State Laboratory of Hygiene

Establishes the accuracy of clinically based taxonomic systems (API 20E, Enterotube) and other emerging taxonomic techniques (gene probe, fatty acid profile) to correctly speciate non-coli Escherichia isolated from drinking water. Incorrect speciation may result in unnecessary public notification and increased monitoring. Published in Journal AWWA, 85(2):74–76, February 1993.

#### A Novel, Sensitive, and Rapid Detection Technology for On-line Monitoring of *Cryptosporidium* Contamination in Water [#552]

University of Colorado at Colorado Springs

Will investigate binding of nucleic acid molecules and magnetized microbeads to surface proteins of *Cryptosporidium* oocysts Will evaluate enumeration of "magnetized" oocysts using detection by microsensor and microchip *To be completed in 2000.* 

### Optimization of Methods for Analyzing Radionuclides in Drinking Water [#529]

Lowry Engineering

Improves the liquid scintillation count method for radon in drinking water. Also demonstrates a new uranium method to be simple, accurate, and less time consuming. Published in 1992. (Out of print)

### Rapid PCR-Based Monitoring of Enteroviruses [#292]

University of Arizona and American Water Works Service Company

Will evaluate the application of an integrated cell culture–polymerase chain reaction (PCR) methodology to rapidly detect infectious viruses in groundwater. Will include optimization of the integrated technique for specific detection of human enteric viruses and a study of the effects of various disinfectants on molecular, cultural, and integrated detection techniques. *To be completed in 1999* 

### Rapid Screening of Pathogens in Water [#2565]

Metropolitan Water District of Southern California (Los Angeles)

Will develop a rapid-screening method for protozoa, enteroviruses, and *E. coli* O157 H7 in water. Will use molecular techniques in a microplate multi-well format. *To be completed in 2001* 

#### The Search for a Surrogate [#65]

AWWA Research Foundation and The Netherlands Waterworks Testing and Research Institute (KIWA)

Describes chemical and biological surrogates for organic micropollutants in drinking water, including analytical techniques, research goals and needs, and the use of surrogates in operational control and monitoring in the treatment plant Published in 1988 (Out of print)

#### A Simple Spectrophotometric Method for the Determination of THMs in Drinking Water [#428]

University of Massachusetts at Amherst

Evaluates a rapid spectrophotometric test for trihalomethanes based on the Fujiwara reaction Describes the method developed and provides performance data and the results of field testing Published in 1992 (Out of print)

### UV-VIS Spectroscopy for the Rapid On-Line Detection of Protozoa [#162]

University of South Florida

Will develop instrumentation based on ultraviolet-visible (UV–VIS) spectroscopy for use as an on-line particle analyzer to detect, identify, and quantify *Cryptosporidium* oocysts and *Giardia* cysts *To be completed in 1999.* 

### Vital Dye Staining of *Giardia* and *Cryptosporidium* [#160]

University of Alberta

Reports on a vital stain for *Giardia* cysts and *Cryptosporidium* oocysts that can be incorporated into the immunofluorescence assay (IFA) for drinking water Covers sources of error and interferences and their impact on the IFA. Also describes tests of the vital stain in several natural waters and its "ruggedness" in different laboratories. Published in 1997. (*Order 90733*)

### Automated Monitoring and Instrumentation

#### Applications Guidance for Particle Counting Technology at Drinking Water Utilities [#456]

City of Calgary (Alta.) Waterworks, Environmental Engineering & Technology, Inc., and the City of Milwaukee (Wis.)

Will develop a consensus approach to using particle counting technologies, including instrumentation needs, installation, data acquisition and analysis, quality assurance, and applications in drinking water utilities. *To be completed in 2000.* 

#### Assessment of TOC Analytical Accuracy With Reference to the Disinfectants/ Disinfection By-products Rule [#452]

Academy of Natural Sciences of Philadelphia, U.S. Geological Survey, and Philadelphia Suburban Water Company (Bryn Mawr, Pa.)

Will quantify the analytical accuracy of the total organic carbon analytical methods, including evaluation of a particulate organic carbon standard and the ability of both analytical methods to accurately measure particulate organic carbon. *To be completed in 1999*.

#### Automated Measurement of Aqueous Ozone Concentration [#519]

University of California at Davis and Texas Technological University

Develops and evaluates two automated methods for measuring aqueous ozone concentration. One technique focuses on the transfer of ozone from the aqueous phase to the gas phase for measurement by proven ultraviolet spectroscopy techniques. The second approach focuses on the measurement of ozone directly in water using the indigo trisulfonate method. Published in 1993. (Out of print)

#### Design of Early Warning and Predictive Source Water Monitoring Systems [#2527]

To be determined

Will develop early warning and source water monitoring systems for real-time contaminant monitoring. These systems would allow operators to predict water quality events that may tax subsequent treatment processes. *To be completed in 2001*.

### Development of a Differential UV System for On-Line Monitoring of DBPs [#2563]

University of Washington

Will help validate the concept of using differential UV spectroscopy to monitor DBPs in distribution systems. Will also identify and address limitations to the practical implementation of this approach. *To be completed in 2001*.

#### Development of a Size and Count Calibration Standard for On-Line Particle Counting [#454]

Camp Dresser & McKee and Syracuse University

Will create a standard calibration material and develop standard procedures for particle counters that will allow on-line calibration for particle size and count. *To be completed in 2000.* 

#### Development of Fiber Optic Chemical Sensors for Monitoring Organic Compounds [#417]

ST&E Inc.

Discusses fiber-optic-based chemical sensors for on-line and in-situ analysis of trichloroethylene, total organic carbon, and total organic chlorine. Published in 1996. (Out of print)

## Evaluation of Particle Counting as a Measure of Treatment Plant Performance [#505]

City of Calgary (Alta.) Waterworks and Bigelow Laboratory for Ocean Sciences

Assesses particle size analysis as a means of optimizing the filtration process. Evaluates sampling protocols and commercially available particle-counting instruments. Includes a pilot-scale study of pathogen removal and an evaluation of filtration processes. Published in 1992. (Order 90595)

#### An Evaluation of Streaming Current Detectors [#113]

University of Delaware and City of Newark (Del.) Water Dept.

Evaluates conditions that allow use of streaming current detectors by drinking water treatment facilities, focusing on water quality and treatment processes. Published in 1988. (*Order* 90536)

### Improved Methods for Isolation and Characterization of NOM [#159]

University of Washington, University of Poitiers (France), U.S. Geological Survey, HDR Engineering, Inc., SAUR, and Dynamco, Inc.

Will develop and demonstrate techniques for isolation and characterization of natural organic matter. Will emphasize new, simple approaches that can be carried out in a utility laboratory. *To be completed in 1999*.

#### Particle Image Velocimetry [#291]

State University of New York at Buffalo

Will determine the potential use of particle image velocimetry (PIV) in water treatment studies. Will use the method in jar test studies to obtain information on turbulence and particle size characteristics useful in the interpretation of results. *To be completed in 1998*.

### Practical Application of On-Line Monitoring [#2516]

McGuire Environmental Consultants

Will review existing on-line monitoring technologies to identify operational and maintenance requirements. Will document successful on-line monitoring operations as well as problems encountered, and will develop a guidance manual that assists utilities with the application, maintenance, and calibration of on-line monitoring instruments. *To be completed in 2001*.

### A Practical Guide to On-Line Particle Counting [#835]

City of Calgary (Alta.) Waterworks

Provides information for utilities to put particle counters on-line. Focuses on six areas: sampling configuration, sensor flow control, particle concentration and size issues, sensor intercalibration, data presentation, and quality assurance. Published in 1995. (*Order* 90674)

#### Quantitative Particle Count Method Development: Count Standardization and Sample Stability/Shipping Considerations [#266]

Malcolm Pirnie, Inc., and University of Texas

Will evaluate sample stability and the potential for standardized quantitative particle count analysis for drinking water quality monitoring. Will provide broader access of particle counting technology to water utilities. *To be completed in 1998.* 

### A Study of Low-Level Turbidity Measurements [#2560]

Syracuse University

Will determined if factors such as the source and type of instrument and the type of calibration material have a statistically significant effect on low-level turbidity measurements for different sources of filtered water. Will also provide information about commercial calibration materials such as their tendency to change with time, their consistency of quality, and if their performance varies with the source of the filtered water sample. *To be completed in 2000*.

### Monitoring Programs and Interpretation of Data

### Assessment of Blue-Green Algal Toxins in Raw and Finished Water [#256]

Wright State University, University of Alberta, University of Wisconsin, and Metropolitan Water District of Southern California (Los Angeles)

Will evaluate the occurrence of algal toxins in North American water sources. Will investigate correlations or lack thereof between toxin occurrence and taste and odor episodes. Will develop guidance for monitoring algal toxins and recommendations for responding to potential safety concerns. Research partner: USEPA. To be completed in 1999.

#### AWWARF Trihalomethane Survey [#236]

Metropolitan Water District of Southern California (Los Angeles) and Decision Research

Reports results of a survey designed to determine nationwide levels of THMs in drinking water, estimate costs associated with removal of THMs, and assess effect of lowered THM standards. *Published in Journal AWWA*, 80(1):61–68, *January* 1988.

#### Cryptosporidium Risk Checklist for Water Utilities [#440]

Health Research, Inc., and the State University of New York at Albany

Will synthesize results from related past and ongoing research and will develop a checklist identifying both watershed issues and treatment factors that may affect potential risks to a water utility from *Cryptosporidium*. Will provide guidance to utilities for applying the checklist and interpreting the results once potential risks have been identified. Research partner: Health Research, Inc. *To be completed in 1999*.

### Adentification and Occurrence of Ozonation By-Products in Drinking Water [#510]

University of North Carolina at Chapel Hill, Metropolitan Water District of Southern California (Los Angeles), and James M. Montgomery Consulting Engineers

Through laboratory experiments using advanced analytical techniques on concentrated fulvic acid solutions, identifies suspected and unknown ozonation by-products. Also examines ozone by-product occurrence in two field surveys at utilities using ozone at full- or plant-scale. Published in 1993. (Out of print)

#### Identification of Mutagenic By-products From Aquatic Humic Chlorination [#326]

University of North Carolina at Chapel Hill

Identifies chemical structures and concentrations of reaction products of chlorine and humic acids responsible for the mutagenic response of drinking water residues in the Ames histidine reversion assay with strain TA1000. Also evaluates Ames tester strains TA97, 102, and 104 for measuring mutagenicity of humic chlorination by-products. Uses the TOX method to chemically track halogen substitution and to identify major components of TOX that show positive responses in the Ames reversion assay. Published in 1990. (Out of print)

### Survey of Bromide in Drinking Water and Impacts on DBP Formation [#825]

University of Colorado

Characterizes bromide levels at 100 water utilities throughout the United States selected to reflect a diversity in water sources. Evaluates seasonal variations at 50 utilities. Also determines ozone-based formation potentials on all samples to give an indication of potential bromate formation. Published in 1995. (Out of print)

### Viral and Microbial Methods for Groundwater [#726]

AWWA Research Foundation and USEPA

Will evaluate new screening technologies with conventional tissue culture methods to monitor for the presence of enteric viruses in groundwater. Will also include surrogate indicators such as total coliforms, fecal coliforms, coliphage, *E. coli, Clostridium* spp., etc. Will determine which microbial indicators are best for monitoring enteric viruses. Research partner: USEPA. *To be completed in 1999*.

#### Virus Occurrence Survey [#186]

American Water Works Service Company

Will conduct a survey on the occurrence of viruses in groundwaters that are not under the influence of surface water and that are extracted from properly constructed drinking water wells. Will use both the PCR technique and traditional tissue culture methods. Research partner: USEPA. *To be completed in 1999*.

#### MANAGEMENT AND ADMINISTRATION

#### **Organization Structure**

#### Alternative Management of Small Systems: Rural Electric Cooperatives [#823]

Electric Power Research Institute, National Rural Electric Cooperative Association, Kennedy/Jenks Consultants

Provides a feasibility study and economic analysis for evaluating the role of rural electric cooperatives to manage and operate small water systems. Presents case studies of rural electric cooperatives providing significant assistance to water and wastewater utilities, especially contract operation and maintenance services. Also includes results of a survey of U.S. rural electric cooperatives to assess their overall interest in future involvement with small water utility operations. Rural Water/Wastewater Study. Volume 1: Background, Terminology, and Recommendations was published in 1992. (Order EPRI TR-100820, available only to AWWARF subscribers.) Nonsubscribers, including AWWA members, can order from EPRIAMP Customer Assistance Center, 800-432-0267.

### Balanced Evaluation of Public-Private Partnerships [#455]

CH2M Hill

Will develop guidance and formats for drinking water utilities to evaluate costs and benefits of public–private partnerships (e.g., outsourcing of services, transfer of ownership) for the purpose of optimizing utility services that fulfill long-term customer requirements. *To be completed in 1999.* 

### **Balancing Multiple Water Quality Objectives** [#834]

Camp, Dresser & McKee, Inc., Santa Clara Valley Water District (San Jose, Calif.), and San Francisco (Calif.) Water Dept.

Addresses the challenge of balancing multiple, and often conflicting, water quality objectives, such as disinfection and disinfection by-product control, taste and odor control, biological regrowth control, filtration, and corrosion control. Reports simultaneous optimization of the entire treatment process train at two case study utilities. Extends the case studies to provide a framework and guidance document for use by other utilities. Published in 1998. (Order 90745)

#### Compliance Guidance and Model Risk Management Program for Water Treatment Plants [#272]

Roy F. Weston, Inc.

Develops a model risk management program (RMP) to allow utilities to develop their own site specific RMP. Addresses proposed USEPA RMP regulations, existing OSHA process safety management regulations, and relevant emergency planning and state RMP rules. Provides a model RMP and guidance for utilities to comply with applicable regulations. Research partner: USEPA. Published in 1998. (*Order 90760*)

#### Cost Allocation and Rate Design for Water Utilities [#640]

The National Regulatory Research Institute

Investigates cost allocation and rate design for water utilities. Helps water utilities meet the emerging rate design challenges caused by higher costs to meet drinking water regulations, to install new treatment technologies, to add capacity, and to accommodate changes in pricing policies that may encourage conservation. Published in 1991. (Out of print)

#### Development of a Capital Planning Strategy Manual [#2520]

To be determined

Will develop a capital planning strategy manual for water systems that would integrate decision-making tools for prioritizing and financing rehabilitation and replacement programs. *To be completed in 2001.* 

#### Development of a Decision Process for Prioritization of Emerging Pathogen Research [#2503]

Technology Planning and Management Corporation and University of North Carolina at Chapel Hill

Will use a series of expert workshops in which established decision-making tools would be employed to develop a process for identifying emerging waterborne pathogens of concern as well as future research priorities. Research partner: USEPA. *To be completed in 2001*.

#### **Energy Management for Water** and Wastewater Utilities [#736]

Electric Power Research Institute, AWWA Research Foundation, and Water Environment Research Foundation

Provides a detailed look at electricity consumption for several generic processes used in water and wastewater plants. Describes energy usage patterns for water and wastewater. Also identifies opportunities for a variety of energy management options. Includes energy management approaches and case study applications. Published in 1994. (Out of print)

## Estimating the Cost of Compliance With Drinking Water Standards: A User's Guide [#820]

RCG/Hagler Bailly, Inc.

Provides a cost estimating protocol that objectively and accurately predicts the national cost to comply with drinking water regulations. Includes peer-review by representatives from the water supply community, legislative groups, and regulatory agencies. Published in 1996. (Out of print)

### Feasibility of Small System Restructuring to Facilitate SDWA Compliance [#185]

RCG/Hagler Bailly, Inc.

Investigates the potential for regionalization on a state-by-state basis and assesses the feasibility and economic cost and impact. Analyzes restructuring options including physical interconnection and satellite management. Also reviews institutional barriers that may preclude regionalization even if it is both physically and economically feasible. Published in 1997. (Order 90720)

### Financial–Economic Impacts of a Water Main Replacement Program [#462]

Apogee Research, Inc., Roy F. Weston, Inc., McGuire Environmental Consultants, Inc., and Rose Enterprises, Inc.

Will analyze the economic planning, asset management planning, and accounting issues surrounding a long-term capital-intensive program of installing the next generation of pipeline infrastructure. Will use case studies to identify alternative policies and practices that optimize infrastructure maintenance and replacement programs. *To be completed in 2001*.

#### Guidance for Self-Assessment and Peer Review for the AWWA QualServe Program [#246]

RPG Consulting and Roy F. Weston, Inc.

Provides handbooks for water utilities to use in conducting self evaluation and peer review. Published in 1997. (*Out of print*)

### Implementation of Institutional Arrangements for Small Systems [#329]

American Water Works Association

Looks at costs, revenues, and rates appropriate for a viable small water system, and at the feasibility of central cooperatives for the management of small systems. AWWA completed guidance documents in 1992.

#### Institutional Alternatives for Small Water Systems [#79]

Kelley, Gidley, Blair and Wolfe, Inc.

Provides guidance to legislators, planners, county officials, and public interest groups concerned with public water supplies on the topics of (1) the status and problems of small water systems, (2) sources of financing, (3) proliferation of small water systems, (4) national experiences on the uses of various institutional alternatives, and (5) regulatory agencies' assistance. Published in 1986. (Out of print)

#### Learning From Other Industry Deregulation Experiences: Identify Trends and Opportunities for Water Utilities [#2515]

To be determined

Will review the ways in which recently deregulated utilities or industries have modified business practices to embrace more competitive modes of operation and identify the lessons to be learned by water supply utilities from such changes. Will identify potential opportunities to partner or negotiate with deregulated utilities. *To be completed in 2001*.

#### Management Strategy Manual for Water Treatment Plant Infrastructure Assessment [#460]

Camp Dresser & McKee, Inc.

Will produce a manual for use by water utilities in developing strategic plans for water treatment plant infrastructure maintenance and renewal, including condition assessment procedures. *To be completed in* 2000.

### Managerial Assessment of Water Quality and System Reliability [#257]

Apogee Research, Inc., Malcolm Pirnie, Inc., and Metropolitan Water District of Southern California (Los Angeles)

Describes use of an American Assembly approach to convene water utility managers to produce a consensus document for the managerial assessment of water quality and system reliability. Provides a holistic source-to-tap framework for organizing the measures to assure reliability that can serve as benchmarks to anticipate future needs and strategic initiatives. *Includes a 14.5-minute VHS video*. Published in 1997. (*Order 90725*)

### Meeting Future Financing Needs of Water Utilities [#707]

Wade Miller Associates, Inc.

Provides water utilities with a framework for effective financial planning in view of the need for new facility investments or improvements to existing supply systems. Covers strategies for reducing financial risk, enhancing the reliability of revenue streams and cash flow, using innovative rate-making practices to meet financial objectives, and maximizing access to low-cost capital. Also discusses the principal factors used by the investment community to evaluate a utility's credit-worthiness and a template model for utility managers to use to assess their credit-worthiness. Includes small system financing strategies. Published in 1993. (Out of print)

### Meeting the Management, Organizational, and Staffing Challenges of the 1990s [#705]

Wade Miller Associates, Inc.

Provides guidance to assist water utility managers in (1) identifying the major management challenges that confront their organizations, and (2) developing an appropriate strategic response to these issues. Published in 1993. (Out of print)

### Performance Benchmarking for Water Utilities [#164]

WRc inc. and Municipal Financial Services Group

Determines areas of water utility operations and management that would be appropriate for developing benchmarks to evaluate utility performance. Includes suggestions that water utility managers would be able to use to evaluate and improve performance of their individual operations. Published in 1996. (Order 90710)

### Putting Strategy to Work: Tools for Cost and Quality Management in the 1990s [#523]

Cresap—A Towers Perrin Company

Compiles information about various cost management approaches. Includes a series of handbooks that document current electric- and water-utility experience in reducing operating costs. Also adapts strategic cost management tools from other industries to the electric-power and water-supply fields. Published in 1992. (Order EPRI TR-100052, V1-5, available only to AWWARF subscribers.) Nonsubscribers, including AWWA members, can order from EPRIAMP Customer Assistance Center at 800-432-0267.

### Quality Energy Efficiency Retrofits for Water Systems [#298]

HDR Engineering, Inc.

Provides pragmatic information to increase the likelihood of high quality, reliable, and persistent energy management retrofits. Includes information on how to avoid common pitfalls and problems, suggestions for selecting contractors, and how to evaluate completed projects. Research partners: California Energy Commission and EPRI CEC. Published in 1997. (Order CR-107838, available only to AWWARF subscribers.) Nonsubscribers, including AWWA members, can order from EPRIAMP Customer Assistance Center at 800-432-0267.

#### Water Affordability Programs [#184]

National Consumer Law Center

Reports a comprehensive survey of affordability rates/programs now being offered by U.S. water utilities. Provides both case studies and an evaluation of the rates/programs against a set of criteria for measuring the viability and value of such efforts. Published in 1998. (*Order* 90732)

#### Workforce Planning and Development [#2517]

Hagler Bailly Services, Inc., and EMA Services, Inc.

Will provide guidance on workforce planning that would address modern and innovative utility business practices. *To be completed in 2001.* 

#### **Management Information Systems**

#### Assessing Utility Communication Architecture [#711]

Automatic Meter Reading Association

Assesses the electric industry's standard communication protocol (utility communication architecture or UCA) to determine if the water industry should participate in the modification of UCA to include water applications that would allow different automatic control systems within water utilities (such as SCADA, Customer Information Systems, and real-time network models) and systems made by different manufacturers to exchange information. The project was completed in 1992, and a summary is available upon request.

### Automatic Meter Reading for the Water Industry [#517]

United Water Resources, Automatic Meter Reading Association, and the Institute of Gas Technology

Examines the state-of-the-art and the economic feasibility of automatic meter reading (AMR) Evaluates AMR standardization needs and impacts Published in 1992 (Out of print)

### Automation Management Strategies for Water Treatment Facilities [#811]

EMA Services, Inc

Provides guidelines for the implementation of automated operation of treatment plants and other facilities according to their complexity and treatment technology. Addresses the concerns of utility and regulatory agencies, and allows utilities to more fully realize the benefits and economies of automation. Published in 1996. (Out of print)

### Demonstration of Utility Communication Architecture [#240]

San Antonio (Texas) Water Services

Will demonstrate the application of utility communication architecture (UCA) for distribution automation Will evaluate the benefits of UCA and provide guidelines for its implementation Research partner EPRI *To be completed in* 2000.

### Energy and Water Quality Management System [#299]

EMA Services, Inc , and East Bay Municipal Utility District (Oakland, Calif)

Based on a pilot project, provides a methodology and guidelines for evaluating various designs for energy management systems that will be part of a utility SCADA system. Determines the benefits of a water-quality-constrained energy management system Bases benefits on a variety of alternative future scenarios for energy management, including electric utility deregulation. Research partner. EPRI CEC Published in 1997. (Order C0002, available only to AWWARF subscribers.) Nonsubscribers, including AWWA members, can order from EPRIAMP Customer Assistance Center at 800-432-0267.

## Feasibility Study to Develop an Artificial Intelligence System for Optimization of Water Treatment Plant Operations [#2510]

University of Alberta, Metropolitan Water District of Southern California (Los Angeles), and AQUALTA, Inc

Will identify a number of plant-wide water quality and operational parameters that can be measured on-line (real time). Using sophisticated computer process control algorithms, will develop an artificial intelligence system that would use historical water quality and operational data to make operating decisions that would optimize water treatment performance. To be completed in 2001.

### Implementing Successful Geographic Information Systems [#622]

American Public Works Association

Describes existing municipal uses of automated mapping/facility management systems, and provides guidelines to facilitate cooperation among all potential users in a geographic area Published in 1996 by APWA (The GIS report is available only to AWWARF subscribers.) Nonsubscribers, including AWWA members, can order from APWA Public Works Bookstore, 2345 Grand Blvd, Suite 500, Kansas City, MO 64108-2625, telephone, 816-472-6100, fax, 816-472-1610

### Instrumentation and Computer Integration of Water Utility Operations [#434]

AWWA Research Foundation and Japan Water Works Association

Reports on the state of technology currently being used in the computer automation of water systems operations. Includes a "picture" of what a totally integrated water system would look like in the year 1996, and identifies the barriers to be overcome and the research needed for the industry to achieve that goal Published in 1993. (Out of print)

#### Joint Utility Meter Reading: Development of a Common Platform and Process [#367]

EMA Services, Inc , Plexus Research, Inc , Institute of Gas Technology and Automatic Meter Reading Association

Will provide an understanding of the technological and institutional issues surrounding joint meter reading Will document the business case for joint metering, which includes improving efficiency and customer service. Will also identify various strategies that utilities might pursue to move toward collaborative meter reading and, possibly, shared billing and customer service. Research partner. EPRI CEC. To be completed in 1999.

### Knowledge-Based Expert Systems in Water Utility Operations and Management [#324]

Syracuse University and Clarkson University

Assesses feasibility of using computerized knowledge-based expert systems for treatment plant operations. Also provides system prototypes that capture expertise of engineers and operators with regard to operation of representative facilities and demonstrates capabilities of such systems to act as practical operations aids. Published in 1989. (Order 90560)

#### Natural Organic Matter in Drinking Water: Recommendations to Water Utilities [#2543]

Parsons Engineering Science, Inc

Will critically evaluate research results on NOM in drinking water and provide recommendations to utilities on how to use the information *To be completed in 2000*.

### Total Energy and Water Quality Management System [#458]

Westin Engineering, Inc

Will facilitate a users' forum of water and electric utilities to prepare a generic model for an energy and water quality management software system for the water community Based on the generic model, will develop standard specifications for the software applications required to minimize energy costs within the constraints of water quality and operations goals Research partner EPRI CEC To be completed in 1999.

## The Use of Artificial Neural Networks for Process Modeling and Control of Enhanced Coagulation [#391]

University of Alberta

Will develop and evaluate artificial neural network (ANN) models for clarified water turbidity and total organic carbon. Will determine which factors are most important in optimizing enhanced coagulation. Will also develop protocols for source data analysis, model architecture selection, model training, and model evaluation. Will study the use of ANN models in process control. To be completed in 1998.

### Using the Utility Business Architecture to Become More Competitive [#374]

EMA Services, Inc , and Colorado Springs (Colo ) Utilities Dept

Will apply the utility business architecture (UBA) to improve work practices. Will include selection of business processes for re-engineering, creation of an "as-is" picture, and development of an improved "to be" picture. To be published in 1999.

#### Using the Utility Business Architecture to Build a Performance Center [#346]

EMA Services, Inc , and Metropolitan Water District of Southern California (Los Angeles)

Will apply the utility business architecture (UBA) to develop an operations performance center, that is, a software tool, that can be used by operators Will enable operators to monitor a performance index that accounts for cost and for achievement of water quality goals *To be completed in 1999*.

### The Utility Business Architecture: Designing for Change [#165]

EMA Services, Inc , and Enterprise Engines

Describes a common architecture (or model) for water utility computer generated data that would enable the exchange of data between different software applications used in development, treatment, distribution, and management of water Includes the definition of common water utility business and operational objectives, the development of a set of functional definitions for the various operations within a water utility, and the assessment of data needs for each function Also *includes a 13-minute VHS video* Published in 1997 (*Order 90726*)

## Utility Communication Architecture (UCA) for the Integration of Water Utility Computer Systems [#822]

Electric Power Research Institute and EMA Services, Inc

Will modify the electric industry's standard communication protocol (UCA) to allow communication among different automatic control systems within water utilities (such as SCADA, Customer Information Systems, and real-time network models) and systems made by different manufacturers Research partner EPRI *To be completed in* 1999.

### □ WALTER Version 1.0—A System to Aid Operators of Water Treatment Plants [#532]

Clarkson University

Presents an expert system to help diagnose and explain recurring problems associated with the five major surface water treatment processes (chemical addition, flocculation, sedimentation, filtration, and chlorination) The expert system or diagnostic-aid package runs on an IBM-PC compatible computer and includes a user manual Published in 1994 (Order 90646)

#### Public Education and Communication

### The AWWARF Consumer Attitude Survey Update [#394]

Robert Hurd & Associates, Inc.

Will update the 1993 survey (project #802) by collecting current survey data in 1996-97 at the national level; tracking new trends in public confidence and expectations, perceptions, and satisfaction; and identifying the driving factors behind these attitudes and trends, and assessing the impact of media on public confidence and customer satisfaction. Will also discuss the implications of these findings for measuring customer attitudes at the local utility level. *To be completed in 1999*.

### Consumer Attitude Survey on Water Quality Issues [#802]

Apogee Research, Inc.

Describes a telephone survey of 1,603 adult consumers in the United States to determine their views on water quality issues and the water utility industry. Includes results of interviews with a small cross section of environmentalists, mayors, and water utility general managers nationwide. Also covers a follow-up survey to assess the impact of the cryptosporidiosis outbreak in Milwaukee on public attitudes and perceptions in Milwaukee as well as the rest of the nation. Research partner: AWWA. Published in 1993. (Out of print)

## Customer Satisfaction: Best Practices for a Continually Improving Customer Responsive Organization [#2525]

Black & Veatch

Will identify customer service strategies, processes, and measurement tools to develop standardized, innovative, and easily implemented programs for water utilities. *To be completed in 2001*.

# Demonstration/Evaluation of the Potential of Public Involvement in Preventing Future Invasive Alien Plant Problems in the East Maui Watershed [#2540]

Maui (Hawaii) County Board of Water Supply

Will develop a proactive approach to managing invasive alien plants through early detection, establishment of information support, formation of effective control protocols, and timely response, using public involvement in all phases. Research partner: Maui County Board of Water Supply. To be completed in 2001.

#### A Preliminary Assessment of Water Utility Monitoring Needs Under the Safe Drinking Water Act [#301]

Wade Miller Associates, Inc.

Provides a methodology for utilities to use to determine costs of in-house analytical capabilities, based on documentation of capital and operational costs of compliance with existing, proposed, and projected monitoring requirements developed under the 1986 amendments to the SDWA. Published in 1988. (Out of print)

#### Process Benchmarking in the Water Industry and Development of Customer Satisfaction Measurements [#359]

Roy F. Weston, Inc., Robert Hurd & Associates, Inc., and Apogee Research, Inc.

Will design a framework for process benchmarking in the water industry. Will define key process features of water utilities and will present key benchmarking needs as defined by utilities. Will also formulate a standard set of processes and normalized questions to determine customer satisfaction with common customer contact functions. To be completed in 1999.

#### Protocol for *Cryptosporidium* Risk Communication for Drinking Water Utilities [#444]

Carnegie-Mellon University

Will develop written protocols for implementing voluntary and mandated *Cryptosporidium* risk communication programs, using standard consumer marketing strategies and established risk communication techniques. Will provide methods for utilities to measure the effectiveness of the programs. *To be completed in 1999*.

#### Public Attitudes Toward Water Utilities [#115]

Audits and Surveys, Inc.

Reports results of a statistically valid random telephone survey of U.S. households on public water systems concerning attitudes toward drinking water quality, safety, and costs. *Published in Journal AWWA*, 78(6):34–40, *June 1986*.

#### Public Involvement Strategies: A Manager's Handbook [#918]

CH2M Hill

Based on research conducted among small and large water utility systems, includes a 10-step process for water utility mangers to use in identifying and planning public involvement strategies. Contains "how to" information throughout the text, helpful strategies for facing tough tasks and avoiding common mistakes, and a catalog of processes and techniques to help implement a public involvement plan. Published in 1995. (Order 90694)

### Public Involvement Strategies: Phase II—Making It Work [#2526]

CH2M Hill

Will validate the 10-step process for developing an involvement plan, and will recommend improvements to either the content, format, or communication medium of the handbook. *To be completed in 2001*.

#### Residential Water Use Patterns [#418]

University of Oklahoma

Establishes residential water use patterns, depicting average total daily usage and what portions are delivered at various instantaneous flow rates. Also relates the data to meter accuracy and endurance data. Published in 1993. (Out of print)

#### A Summary of State Drinking Water Regulations and Plan Review Guidelines [#71]

Utah Dept. of Health and Wade Miller Associates, Inc.

Compares state regulations governing water system design with the purpose of facilitating introduction of new technologies. Published in 1985. (Out of print)

#### Supplemental Services and Products [#499]

Hagler Bailly Consulting, Inc.

Will evaluate the advantages and disadvantages of utility involvement in supplemental drinking water products and services based on customer perceptions and potential income. *To be completed in 2001*.

#### Synthesis Report on Cryptosporidium [#372]

Black & Veatch

Identifies the available information on past, current, and planned research activities concerning *Cryptosporidium* for use by water utility management and the AWWA Research Foundation. Answers questions pertinent to utility operations and management and identifies gaps in the informational base. *Cryptosporidium: Answers to Questions Commonly Asked by Drinking Water Professionals* (*Order 90746*) was published in 1997, and *Critical Evaluation of Cryptosporidium Research and Research Needs* (*Order 90742*) was published in 1998.

#### Tools and Methods to Effectively Measure Customer Perceptions [#466]

Thames Water Utilities (U.K.)

Will evaluate available assessment tools and methods that measure customer perceptions and changes in their opinions toward drinking water utilities and utility services. *To be completed in 2000.* 

#### Water Industry Data Base [#527]

American Water Works Association

Expands past AWWA survey efforts to collect, tabulate, analyze, and report data of relevance to the drinking water industry. Provides a resource for documenting historical information, monitoring current conditions, and forecasting trends. Also contains essential information for planning research needs and for making timely input to legislative and regulatory processes. Completed in 1990. Summary report published in 1992 by AWWA. (Out of print)

#### Water Industry Data Base Update [#275]

American Water Works Association

Updates the previous survey of water utilities serving populations greater than 50,000 (project #527). Also updates some of the categories of information to expand the usefulness of the data base. Research partner: AWWA. Published in 1998 by AWWA as WATER:\STATS. Utility subscribers may contact the Research Foundation directly to check on availability.

#### HEALTH EFFECTS

#### **Risk Assessment Reviews**

### Aluminum, Drinking Water, and Alzheimer's Disease [#818]

HDR Engineering, Inc.

Critically reviews the epidemiologic evidence for the association between aluminum and Alzheimer's Disease. Emphasizes strengths and weaknesses of the previous research designs. Also presents information about the biochemistry and bioavailability of aluminum. Published in 1996. (Out of print)

#### Aluminum in Drinking Water and Alzheimer's Disease: A Resource Guide [#722]

Metropolitan Water District of Southern California (Los Angeles) and San Jose (Calif.) Water Company

Serves as a reference manual for utility managers with inquiries about aluminum and aluminum exposure. Also provides information about health effects and exposure to aluminum, and guidance for understanding and effectively participating in the public communication process. Published in 1993. (Out of print)

## Association Between the Occurrence of Herbicides and Pesticides in Drinking Water and Reproductive Outcomes [#449]

Hagler Bailly Consulting, Inc.

Will review databases and completed studies to determine if there is adequate documentation to conduct an epidemiological study defining the association between the occurrence of herbicides and pesticides in drinking water and reproductive outcomes. To be completed in 1998.

### Drinking Water and Health in the Year 2000 [#643]

Summarizes a workshop and conference sponsored by the USEPA offices of Water and Research and Development and the AWWA Research Foundation. Forty drinking water experts from academia, utilities, USEPA, engineering consulting firms, and nonprofit organizations identified drinking water research needs related to risk assessment, microbes, disinfection and disinfection by-products, inorganic contaminants, synthetic organic chemicals, health effects of DBPs, and competing risks. Published in 1993. (Out of print)

### Guidance Manual for Outbreak Detection [#447]

Provincial Laboratory of Public Health for Northern Alberta and University of Alberta

Will produce a guidance manual for drinking water and public health professionals that will assist them in establishing tracking systems for early detection of gastrointestinal disease outbreaks. Will use continuous input of health data from health care institutions for the information base of the tracking systems. To be completed in 2001.

### Health Effects of Disinfectants and Disinfection By-products [#501]

Washington State University

Reviews existing literature for information on the by-products of chlorine, chloramines, ozone, chlorine dioxide, and other disinfectants. Examines the occurrence and toxicity of disinfection by-products. Also identifies areas in which more research is needed for a better understanding of disinfection by-products and of the ramifications of using various disinfectants. Published in 1991. (*Out of print*)

#### Microbial Risk Assessment [#281]

International Life Sciences Institute

Reports on a microbial risk assessment model of waterborne contaminants for food and water evaluations. The framework developed accounts for qualitative and quantitative information associated with exposure to either a microbiological organism or the media in which the organism occurs. *Published in Risk Analysis*, 16(6):841–848, 1996.

#### Microbial Risk Assessment, Phase II [#484]

International Life Sciences Institute

Will test a conceptual model for conducting waterborne microbial risk assessments that was developed in 1995. Will exercise the framework for *Cryptosporidium* and rotavirus, and then will review the results and render an opinion about the plausibility of the model. Research partner: ILSI. *To be completed in 1999*.

#### Microbial Risk Assessment for Drinking Water [#801]

University of South Florida

Will characterize the risks of pathogenic microorganisms that may be transmitted through drinking water. Will also develop quantitative risk assessment models based upon human dose-response data for a key group of waterborne pathogens. Will address factors such as infectious dose, ratio of clinical to subclinical infections, variations in microbial virulence, host immunity, and mortality rates. Research partner: USEPA. To be completed in 1999.

### Quantifying Public Health Risk Reduction Benefits [#2518]

Stratus Consulting Inc. and Alceon Corporation

Will provide an objective protocol on how a benefits analysis should be conducted and portrayed. This document would be available to USEPA decision-makers and other organizations as an approach for performing cost-benefit determinations. *To be completed in 2001*.

### Review of Health Effects Basis for SOC and IOC Standards [#618]

**EPACH** Corporation

Evaluates the health effects basis of drinking water standards to determine if the standards are consistent with the current scientific interpretation of health data for the chemicals of concern. Published in 1993. (*Order 90609*)

#### State-of-the-Art Review of the Health Effects Basis of Drinking Water Regulations [#318]

Karch and Associates

Documents the best scientific data available for assessing risks of contaminants in drinking water, looking specifically at the health effects basis of lead and THM standards and the risk assessment approach delineated in Volume 7 of Drinking Water and Health. The report could assist the USEPA in setting standards by ensuring that all relevant health effects data are considered. The project was completed in 1989, and a summary is available upon request.

## Update of Review of Health Effects Data on Disinfectants/Disinfection By-products [#448]

Mobull Consulting, Metropolitan Water District of Southern California (Los Angeles), and Camp Dresser & McKee, Inc.

Will provide a critical review of the latest data on the occurrence and toxicity of drinking water disinfectants and disinfection by-products. Research partner: M/DBP Council. *To be completed in 1998*.

#### **Laboratory and Field Studies**

### Arsenic Contribution From Dietary Sources [#560]

Research Triangle Institute

Will refine analytical methods for determining arsenic species in food. Will study contributions of arsenic species from dietary sources, including estimates of speciated and total arsenic in selected foods prepared with water contaminated by arsenic. Will also estimate food and drinking water exposure distributions. Research partner: AsRP. To be completed in 2001.

### Arsenic Effect on Gene Expression [#2551 and #2552]

To be determined

Will examine the impact of arsenic on gene expression and its relationship to cancer and other possible health effects. Will help determine a dose-response relationship for arsenic ingested by humans at low levels in drinking water. To be completed in 2002.

#### Arsenic Human Health Effects: Cancer/ Noncancer Epidemiological Study [#2553]

To be determined

Will provide greater understanding of the nature of human health effects (cancer or noncancer) at low levels of arsenic in drinking water and the associated dose-response relationship. *To be completed in 2002.* 

## Assessment of Molecular Epidemiology of Waterborne *Cryptosporidium* With Respect to Origin [#366]

Metropolitan Water District of Southern California (Los Angeles) and University of California at Davis

Will determine the strain variability of *Cryptosporidium* parvum oocysts using a molecular fingerprinting approach developed from available polymerase-chain-reaction technology. Will describe the genetic characteristics that identify the source of the oocysts. Will also discuss how utilities can incorporate the approach into source water monitoring programs. *To be* completed in 1999.

### Carcinogenic Mechanisms in Rat and Mouse Hepatocytes [#617]

University of Maryland at Baltimore

Examines whether biological systems responsible for the production of chemical free radicals in the presence of certain chemicals commonly present in drinking water (carbon tetrachloride, chloroform, trichloroacetic acid) are responsible for the unique sensitivity of the B6C3F1 mouse to the induction of liver tumors Completed in 1997 A report is available only to AWWARF subscribers.

### Contribution of Waterborne Radon to Home Air Quality [#619]

Roy F Weston, Inc

Investigates the contribution of waterborne radon to home air quality to determine the benefits of adding radon-removal systems to water supplies Published in 1992 (Out of print)

#### Critical Assessment of Radon Progeny Exposure While Showering With Radon-Bearing Water [#171]

Clarkson University

Evaluates kinetics of radon and its progeny and the resulting exposure and radiation dose incurred by individuals during and following showering with radon-laden water. Assesses ventilation, radon progeny concentrations, equilibrium factors, aerosol size, attachment fraction, and other parameters relevant to determining exposure during and immediately following showering. Published in 1996. (Out of print)

## Cryptosporidium parvum: Surrogate Human Pathogenicity Animal Model Using Swine, Phase I [#344]

Utah State University

Will establish and validate an animal model in swine for application to human risks for infectivity and virulence of *Cryptosporidium*, including the quantitative examination of variables such as immunocompetency and age *To be completed in 1999*.

## Cryptosporidium parvum: Surrogate Human Pathogenicity Animal Model Using Swine, Phase II [#354]

Utah State University

Will establish and validate an animal model in swine for application to human risks for infectivity and virulence of *Cryptosporidium*, including the quantitative examination of variables such as immunocompetency and age *To be completed in 2001*.

### Detection of Arsenic in Biological Matrices [#287]

University of Alberta and University of British Columbia

Will develop or improve a quick and inexpensive analytical method to detect human metabolites of arsenic in blood and urine Will also examine methods to preserve arsenic species in urine and water *To be completed in 1999*.

## Development of Methods for Predicting THM and HAA Concentration in Exposure Assessment Studies [#341]

Colorado State University

Will develop predictive tools for exposure assessment to trihalomethanes (THMs) and haloacetic acids (HAAs) for linkage to productive and cancer epidemiological studies. Will use representative groups of waters sparning a typical range of natural organic matter and bromide. Research partner. M/DBP Council. To be completed in 1999.

#### Development of Methods to Detect and Quantify Parent Compounds and Metabolites of DBPs in Human Biological Samples [#489]

University of Florida

Will develop chemical analytical methods for detection and quantification of individual disinfection by-products in blood serum and urine from persons exposed to complex mixtures in chlorinated drinking water Research partner M/DBP Council *To be completed in 2000* 

#### Direct Comparative Genotoxicity Assessment of Disinfection By-products in Drinking Water Generated From Different Disinfection By-products [#554]

University of Illinois at Urbana-Champaign

Will determine toxicity of individual DBPs, mixtures of DBPs, and concentrates of disinfected water in bacterial and mammalian cells. Will examine chlorine, ozone, and the sequence of ozone plus chlorine in addition to chloramination and chlorine dioxide treatment. *To be completed in 2000* 

#### Effect of Dichloroacetic Acid and Trichloroacetic Acid on Cell Proliferation in B6C3F1 Mice [#738]

Environmental Health Research and Testing, Inc.

Examines the role of increased cell proliferation associated with tissue damage (cell death) in the induction of tumors in rodents treated with dichloroacetic and trichloroacetic acids. Published in 1995. (Out of print)

#### Evaluation of Alternative Drinking Water Treatment Processes at Pilot Scale by Means of Mutagenicity Testing [#210]

University of Alberta and City of Edmonton (Alta.)

Examines alternative drinking water disinfection processes by using mutagenicity testing, which uses bacteria and yeast screening procedures capable of giving qualitative information on carcinogenic risk. Published in 1989. (Out of print)

#### Feasibility of New Epidemiologic Studies of Low Level Arsenic [#288]

University of California at Berkeley

Will present epidemiologic study approaches to improve arsenic dose-response data for human health risk assessment, focusing on populations exposed to low levels (25–150 µg/L) of arsenic in drinking water. To be completed in 1998.

## Identification and Quantitation of DNA Adducts Derived From Disinfection By-products [#491]

University of North Carolina at Chapel Hill

Will assess and develop biomarkers that could be used in human studies to quantify internal dose and predict potential health effects from exposure to specific DBPs or families of DBPs. Research partner: M/DBP Council. *To be completed in 2001.* 

### Identification of Geographic Areas for Possible Epidemiological Studies [#384]

Hagler Bailly Consulting, Inc., and Colorado State University

Will identify communities that present a range of exposures to brominated and chlorinated disinfection by-products and for which individual exposures can be reasonably estimated. Will also identify appropriate cancer and birth outcome endpoints and determine the availability of adequate information on these endpoints of concern. Research partner: M/DBP Council. *To be completed in 1999*.

#### Mechanisms of Carcinogenesis by Dichloroacetate and Trichloroacetate [#701]

Washington State University

Will examine whether rodent liver tumors induced by DCA and TCA are produced by a mechanism inappropriate for extrapolation to humans or by a threshold controlled mechanism. *To be published in* 1999.

#### Mechanistic Basis and Relevance of Kidney Tumor Formation in Male Rats for Use in Risk Assessment [#432]

University of Maryland at Baltimore

Evaluates recent findings indicating that, in some instances, tumors are produced in male rat kidneys by a mechanism specific to the species and therefore are not relevant to humans. Determines which regulated drinking water chemicals produce male rat kidney tumors by that male-rat-specific mechanism. Published in 1994. (Out of print)

#### A Prospective Epidemiological Study of Waterborne Transmission of Microbial Disease [#919 and #168]

University of Quebec at Laval

Will compare intestinal disease rates in people exposed to tap water, bottled tap water, purified tap water, and continuous flow tap water to examine whether there is a relationship between drinking water and enteric disease. Will also attempt to determine the relative contribution of treatment and regrowth to disease levels (if any). Research partner: USEPA. To be completed in 1998.

# Public Health Significance of Opportunistic Pathogens in Drinking Water: Molecular Epidemiology of *Pseudomonas aeruginosa* [#268]

University of Washington

Will establish a collection of *Pseudomonas aeruginosa* strains from source waters and compare the genetic fingerprint strains isolated from treated waters and clinical cases in order to assess the public health significance of the presence of *Pseudomonas* in drinking water. Research partners: USEPA and UKWIR. *To be completed in 1998*.

#### Serosurveys to Determine the Attributable Risk of Viral Infection From Groundwater Sources [#2505]

Lovelace Clinic Foundation

Will conduct serosurveys to determine whether attributable endemic levels of enteric virus infection can be estimated in populations exposed to enteroviruses in their groundwater sources. Research partner: USEPA. *To be completed in 2001.* 

## Sodium Arsenite in Drinking Water: Tumor Studies in Heterozygous p53 Deficient Mice [#561]

Integrated Laboratory Systems, Inc.

Will evaluate the carcinogenicity of sodium arsenite as a function of hepatic methyl donor status. Will also investigate the ability of sodium arsenite to promote bladder carcinogenicity and skin carcinogenicity as a function of hepatic methyl donor availability. Will report findings from investigations using heterozygous p53 deficient male mice receiving chronic administrations of arsenic in drinking water. Research partner: AsRP. *To be completed in 1999*.

#### Two City Cryptosporidium Study [#177]

The Southwest Center for Managed Care Research

Will examine the occurrence of cryptosporidiosis in a population consuming groundwater with that of one consuming surface water. Using a comparison of the relative infection rates, will provide an estimate of the relative contribution of water to infection rates. *To be published in 1999*.

#### Validation of Serology Method for the Detection of *Cryptosporidium* in Human Populations [#438]

University of British Columbia

Will test and validate *Cryptosporidium*-specific serologic assays by determining antibody sensitivity and specificity in a variety of populations. Will determine the duration of antibody response after exposure to *Cryptosporidium*. To be completed in 2000.

#### **TECHNOLOGY TRANSFER**

#### Collaborative Research

The purpose of the Collaborative Research Program is to interact with other research organizations. One example is the Research Foundation's efforts with the Electric Power Research Institute's (EPRI's) Community Environmental Center (CEC) to discover, develop, and deliver research projects focused on energy management and electrotechnologies for water utility processes. The program has evolved recently to include several project areas that have AWWARF-EPRI co-funding and co-management. There has been much cooperation in the technology transfer activities of both research groups and their respective utility audiences. The synergy between water and electric utility operations and customer bases provides the opportunity for continued, applied research efforts.

#### **Emerging Technologies**

The AWWA Research Foundation, in cooperation with various drinking water research groups from around the world, biannually convenes Emerging Technologies Seminars. These meetings are part of an ongoing effort to identify emerging water treatment technologies. The notebook from the 1998 seminar (ETVIII) is available on AWWARF's website at http://www.awwarf.com/etviii/etintro.htm

#### Newsletters

The Technology Transfer group publishes three newsletters to keep people in the water industry up to date on the foundation's research program. *Drinking Water Research*, a bimonthly publication, reports on AWWARF projects and activities. It is provided as a free service to members and subscribers, and is available to others on a subscription basis.

Research Direct, a fax newsletter for subscribers, provides brief updates on AWWARF programs and activities.

Twice a year, the foundation publishes *Research et al.* to inform researchers of new developments in the research program. This newsletter announces requests for proposals, AWWARF meetings, and research project selections. It is sent at no charge to AWWARF contractors and other interested parties.

#### **Research Applications**

The Research Applications Program is designed to bridge the gap between research and the practical application of that research by water utilities. This program investigates ways to remove barriers to implementation of research.

The applications program has three components designed to address these barriers:

- Demonstrating completed projects in partnership with subscribing utilities
- Documenting the costs and benefits of applying research
- Developing new and innovative ways to promote the application of research

A variety of initiatives have been started to address these components. Most of these initiatives are described elsewhere in this publication. There are also the publications *Research Applications*, which highlight applications of various research results for which quantifiable benefits have been calculated.

#### Tailored Collaboration

In June 1996 the Foundation's Board of Trustees approved the Tailored Collaboration (TC) program for full utility subscribers. The purpose of the TC program is to provide for direct utility subscriber involvement in research projects that are of specific interest. But in a broader sense, the program will also contribute to the overall knowledge base available to the water community. Another benefit of the TC program is an expanded research funding base without an increase in subscription fees.

#### **Technology Transfer Conferences**

The AWWA Research Foundation organizes
Technology Transfer Conferences to inform subscribers
about the results and applications of centralized
research programs. At these meetings, principal
investigators describe their work, emphasizing results
with immediate impact for the water industry.

Foundation staff consult with AWWARF subscribers to develop conference programs of regional interest. The locations for the conferences held each year are chosen to provide access for as many subscribers as possible. Subscribers receive complimentary registrations to these meetings as part of their subscription benefits.

#### **Videotapes**

The AWWA Research Foundation produces videotapes to communicate the results of its research projects.

Currently, twelve videotapes are available on loan.

- (1) The Ozone Option discusses various ozone projects.
- (2) Colilert: A Better Method for Ensuring Drinking Water Quality describes the analytical method for total coliforms and E. coli.
- (3) Lead Control Strategies presents concepts related to controlling lead in drinking water.
- (4) GAC—The Adsorption Option for Organics Removal covers use of granular activated carbon in filteradsorbers, post-filter adsorbers, and GAC contactors.
- (5) Taste and Odor in the 90's focuses on flavor profile analysis.
- (6) Facing Facts tells the story of the AWWA Research Foundation and its utility-funded research program.
- (7) The Balancing Act: Disinfection and Disinfection By-product Control provides an overview of the issues involved in balancing the trade-offs between disinfection and disinfection by-product control.

- (8) Spotlight on Water Resources Research highlights various water resources projects.
- (9) Disinfection By-product Precursor Control, a companion to The Balancing Act video, focuses on four precursor control techniques: enhanced coagulation, GAC adsorption, ozone/biological treatment, and membranes.
- (10) Disinfection: Weighing the Alternatives, also a companion to The Balancing Act video, focuses on disinfectants and treatment techniques for the inactivation of microorganisms.
- (11) Water Treatment Residuals: Issues & Options discusses the need for residual disposal options, types of water treatment plant wastes, methods of characterizing residuals, and disposal options including beneficial reuse.
- (12) Bridging the Gap: Research Applications describes the foundation's Research Applications Program and utilities' use of research.

These productions, ranging in length from 11 to 20 minutes, are available in ½-inch VHS format. They may be borrowed at no charge by calling (303) 347-6243.

#### **ORDER NUMBERS**

Research Foundation Subscribers can order completed reports by writing to AWWARF, 6666 West Quincy Avenue, Denver, CO 80235; by calling (303) 347-6121; by sending a fax to (303) 730-0851; or by sending an e-mail message to rfreports@awwarf.com. Others, including AWWA members, can purchase reports from the AWWA Customer Service by calling (800) 926-7337. *Please note that nonsubscribers can only order reports for completed projects that have order numbers*.

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Advanced oxidation processes Brink, Case,
Oxenford, Ozekin
Air stripping Brink, Case, Kawczynski, Rayburn
Algae controlB. Allen, Hund, Kawczynski
Algal toxinsOxenford
AlumKawczynski
Aluminum, health effectsLomaquahu
Aluminum, residuals Brink, Lomaquahu
Aquifer storage and recovery Martinez, Rayburn
Arsenic Hund, Oxenford,
Popovicova
Assimilable organic carbon Lomaquahu
Automatic meter readingBrink
Bacterial regrowth M. Allen, Brink, Lomaquahu
Benchmarks, utilityBlaha, Martinez
Biological denitrification B. Allen, Brink, Hund
Biological treatment Brink, Hund
Carbon, granular activatedOxenford
Carbon, powdered activated
Cathodic protection Caprara, Lomaquahu
Chloramines Ozekin
Chlorine dioxide Karlin, Oxenford
Coagulation B. Allen, Brink, Karlin,
Kawczynski, Ozekin
Coliforms and fecal coliforms M. Allen,
Hasan, Martin
Colilert test
Collaborative research (EPRI)Kawczynski
Computer automation Brink
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Conservation. B. Allen, Case Consumer attitudes Kawczynski Corrosion, external Caprara, Lomaquahu Corrosion, internal Caprara Cryptosporidium B. Allen, M. Allen, Hasan, Karlin, Lomaquahu, Martin CT values M. Allen, Brink, Karlin, Oxenford, Ozekin
Disinfectant measurement
Electrical grounding practices

Filtration pretreatment	Rehabilita Reservoirs Residuals
Giardia B. Allen, M. Allen, Hasan, Karlin, Lomaquahu, Martin	Risk asses Safe Drink
Giardia analysis	SCADA sy Slow sand Sludge Small syst
Inorganic contaminants	Soil aquife Streaming Surface re Surrogate
Lead control	Synthetic
Membrane filtrationBlaha, Kawczynski, Lomaquahu, Martinez Methods developmentPopovicova	Taste and Trihalome Trihalome
Natural organic matter Oxenford, Ozekin Nondestructive testing	Ultraviole
Organizational staffing Brink Ozonation Brink, Oxenford, Ozekin	Virus ana Viruses
Parasite analysis M. Allen, Hasan, Ilges, Karlin, Lomaquahu, Martin	Volatile o
Particle counting	Water cor Water los Water ma
Pipe, concrete	Water me Watershe Water use Well desi Well resto Wetlands
Radium removal	Zebra mu

Rehabilitation, distribution system Caprara Reservoirs, surface B. Allen, Brink, Kawczynski Residuals Kawczynski, Lomaquahu, Martinez, Morales
Risk assessment Karlin, Rayburn
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Taste and odor Hund, Kawczynski, Popovicova Trihalomethane analysis Kawczynski, Oxenford Trihalomethanes Brink, Karlin, Kawczynski,
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Ultraviolet disinfection
Virus analysis M. Allen, Hasan, Martin Viruses M. Allen, Hasan, Lomaquahu, Reekie Volatile organics removal
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90744	Scheduled J in late		Complimentary						
90745	125.00	195.00	Complimentary						
90746	40.00	55.00	Complimentary						
90747	Scheduled j ın late	for printing 2 1998	Complimentary						
90748		for printing 1998	Complimentary						

Order Number	Domestic Pr AWWA Member	ices <sup>*</sup> (U.S.) Non- Member	AWWARF Subscriber
90749	125.00	195.00	Complimentary
90750	125.00	195.00	Complimentary
90751	Scheduled j in late	for printing 2 1998	Complimentary
90752	125.00	195.00	Complimentary
90753	125.00	195.00	Complimentary
90756		for printing 2 1998	Complimentary
90757	125.00	195.00	Complimentary
90758		for printing 2 1998	Complimentary
90760	125.00	195.00	Complimentary

<sup>\*</sup>Prices subject to change without notice

